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Thesis submitted for the Degree of M.D.

The Development and Histology

of the

Occipital Region of the Brain.

Human and Comparative.

by

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Introductory

This research was carried out in the Anatomical Laboratory of the University of Edinburgh in accordance with the terms of the Vans Dunlop Scholarship in Anatomy awarded me in 1908.

The object of the work has been to study the growth and development and general histology of this important region of the brain, and with this object, where possible, series of brains at advancing stages in development have been examined.

The material investigated has been both Human and Comparative and will be detailed later. The greatest attention has been given to the Comparative work and in this the Ungulates, Carnivores and Rodents figure principally as they have been more easily obtainable. Necessarily many gaps occur in the series owing to the difficulty of obtaining material but in the case of the Sheep, Pig and Ferret, the series of developing brains is practically complete and embryos of only a slight difference in age have been examined. While on a recent visit to the Antipodes, I obtained many specimens of Marsupial and Monotreme brains, but unfortunately these were spoiled during transit.

The interest of any investigation into the Occipital region of the brain centres principally around the Visual area and in the following paper considerable attention will be paid to this, but at the same time, the structure of the other parts of this region will be described and some reference will be made to the development and structure of the Choroid Plexus.

Material examined :-A. Comparative.

1. Complete series of developing sheep brains and adult sheep. The foetal series begins with a 1.5 cm specimen and ends with one at full-time. In the early part of the series specimens have been taken at intervals of 1 or 2 c.ms. in length, and then as age advances the intervals have been increasingly larger until between the two last of the series there has been a difference of 10cms.
2. Series of developing Pigs and adult pig taken in the same way.
3. Complete series of developing Ferrets and adult Ferret.
4. Small series of Cat brains, ranging from a 12 cm foetus to the adult.
5. Adult Dog.
6. Short series of Rabbit brains ranging from a 2 cm foetus to the adult.
7. Adult Guinea-pig.
8. Adult Mole.

B. Human.

1. Foetal. A series extending from the 1st. to the end of the 4th. month.
2. Adult. The Right occipital lobe of a subject whose Right Eye had been enucleated one year before death, and the Calcarine region of the left lobe. The Optic Nerves, Chiasma and Tracts of the same brain have

been /

been examined and the results are given in an appendix but the work on the Cortical changes has not been completed in time to detail in this paper.

Methods of Examination.

Various methods have been employed and numerous difficulties encountered, and a considerable time was spent at the commencement of the work in learning methods before reliable results could be obtained.

1. Preserving Fluids. Formalin 5-10 % has been mostly used. Alcohol of varying strength is also a useful preservative, especially for adult brains.

2. Embedding. The Paraffin method has been largely employed and though it has been satisfactory in the main one has to recognise that considerable shrinkage of the tissues occurs, which may detract something from the accuracy of the result.

The Celloidin Method has been used for some of the Human work but the disadvantage as compared with the Paraffin method is its slowness.

The Paraffin blocks have been cut with a Minot and the Celloidin with a Læitz microtome. In the case of the early members of a foetal series the brains have been cut in serial section and all the sections mounted, but in the larger brains it was found necessary to economise time and material by mounting only every tenth or in some cases every twentieth section. The thickness of the sections has ranged from 7 to 15 micros and the great bulk have been 10 mm. The sections

have /

have been cut in the Coronal or frontal plane commencing at the tip of the occipital lobes and passing forward in most cases well into the parietal area. In the case of the larger brains the examination has been more closely restricted to the occipital lobe. The disadvantage of the coronal method of sectioning in the fissured brain is that the section is apt occasionally to cut the gyri obliquely but usually it cuts the main sulci transversely.

Staining Methods.

a. Cajal's silver method has been largely used and after many trials of the various modifications, one adopted the following method as being the most reliable and generally applicable :-

1. Immerse the pieces of brain which should not be more than a few millimetres thick in 3% Silver Nitrate solution. The presence of the ventricular cavity in the case of the brain permits of the use of comparatively large blocks.
2. Incubate at 37°C. for one week.
3. Wash in distilled water till the tissue is a light yellowish brown (1 - 5 mins)
4. Develop in Pyrogalllic acid formol mixture for 1 or 2 days varying the time with the thickness of the block. In the case of the larger blocks it is advantageous to incubate at 37°C. for at least a part of the time.
5. Wash, after harden in alcohol and mount as usual.

Remarks. It appears to make very little difference whether fresh or fixed tissue is used, and some of my best results have been obtained with fixed or partly

fixed /

fixed tissue. The results are extremely variable, even in cases where all the conditions have been the same and the same occurs in individual sections where some cells may be most clearly defined and others miss the stain almost entirely. In some cases it shows a greater affinity for the Neuroglia than the cells. Again sometimes the fibres stain excellently while the cells remain unstained. In general adult tissue responds much better than foetal. Much trouble was given by the superficial parts becoming over-stained.

b. The Nissl method, in a modified form has proved the most reliable and gives excellent results. After some experimenting the following method was adopted, and can be recommended as giving most satisfactory results for either paraffin or celloidin sections :-

1. Stain in Toluidin Blue. 1/8% heated to 35°C. 10 to 20 minutes.
2. Decolorise in Acetic Acid 3%.
3. Absolute alcohol 2 minutes.
5. Chloroform 2 minutes.
6. Xylol.
7. Mount in Canada Balsam.

c. Haemalum and Eosin as bulk stains have been used in some cases and give good general effects.

Before proceeding to describe the development of the occipital region in the sheep it will be necessary to give a brief outline of the fissures present in this area in the adult animal and their method of development in the foetal series and to discuss briefly the homologies of the more important fissures.

I have studied the development of the fissures in the Ungulate brain (sheep and pig) in a large series of foeti, throughout the whole hemisphere but it will only be necessary for the purposes of this paper to discuss those which are present in the occipital region.

In the adult sheep

the principal sulci are four :-

1. The Calcarine-Intercalary or Splenial-Complex.

This is a very long and deep sulcus which lies in the mesial surface about mid-way between the super-mesial border and the corpus callosum. Anteriorly it turns upwards and usually runs into crucial sulcus at the superior border whilst behind it bends downwards behind the splenium and its lower end is separated from the hinder end of another sulcus, the Rhinic, by a gyrus. This is one of the most interesting and important of the sulci in the ungulates and will be discussed later. It divides the hinder end of the mesial surface into two large gyri, viz. the marginal

and /

and the callosal or gyrus fornicatus and in this latter there is present in the adult and full-time foetus a short and not very deep sulcus, which lies parallel to the long Splenial Complex above the splenium and divides the gyrus fornicatus in this region into two parts. ~~on the lateral surface~~ On the lateral surface :—

2. The Rhinic fissure which is long and deep and extends far back, forms a well marked boundary between the Rhinic area or Pyriform lobe and the overlying Neopallium. It will be noted later that this fissure appears very early and that even before it is visible externally the histological differences between these two great portions of the brain are well marked.

3. The Lateral, the posterior end of which lies not far from the super-mesial border where it forms a deep indentation.

4. The Posterior branch of the Suprasylvian, or post sylvian as Elliot Smith prefers to call it, which lies between 2 and 3 ; said to be characteristic of Ungulates.

Development.

In a 12 cm Foetus,

the Rhinic fissure has appeared as a faint curved groove which passes backwards towards the posterior border of the hemisphere.

In a 13 cm foetus

the Rhinic fissure has become much deeper and longer, and in a mesial surface the Splenial fissure makes its appearance as a short faint, slightly curved /

curved groove lying above the posterior part of the corpus callosum.

In a 18 cm foetus

the Splenial fissure has become much longer and deeper, extends further forwards and curves downwards behind. The Rhinic fissure is still better marked, and the Lateral has appeared as a shallow groove near the Supero-mesial border.

In a 20 cm foetus,

these three sulci have all become much deeper.

In a 27 cm foetus,

these fissures have all become much better marked and the splenial has acquired its adult upturned anterior end. Between the Lateral and the Rhinic fissures the posterior branch of the Suprasylvian has appeared and therefore at this stage all the four main sulci of this region are well developed and this is an important fact in view of the development of the cortex to be detailed later.

Subsequent to this the principal changes up to the adult state consist mainly in an increase in depth and complexity of the neopallial sulci which give off branches, and the appearance between them of some smaller shallow subsidiary fissures.

It may here be stated that in the case of the pig foetal series that the development of the fissures begins a little earlier (10 cms) and advances at a greater pace than in the sheep for a pig of about 15

or 16 cms corresponds very closely in appearance to a sheep of about 20, and a pig of about 20 cms to a sheep of about 27 cms.

Conclusions.

One may hence conclude that for these two Ungulates the most rapid growth of the Neopallial cortex occurs between the stages of 10 and 20 cms, and results in a rapid infolding, to produce the principal fissures, and that there is no trace of the formation of transitory fissures.

The existence of transitory fissures is a debateable point, but is not of sufficient importance here to require discussion.

Morphology and History.

This will be dealt with very briefly for the subject is so complicated and the literature and diversity of opinion so great that more than a brief reference to it would be out of place in this paper.

The Calcarine-Intercalary or Splenial fissure is extremely interesting from the point of view of homologies and a very great deal has been written about it. Julius Krueg in 1878 wrote an excellent account /

account of the fissures in the ungulate brain and described their development and I shall refer to his paper at some length for there are some notable differences between his account of the four main sulci which concern this region and that already given. Krueg named the long sulcus present in the posterior part of the mesial surface the "Sphenial" taking his name from the adjoining Splenium Corporis Callosi and later Continental writers extended the name to "Splential Complex" thus taking into account the anterior or Intercalary part of the fissure as a distinct entity.

2. Elliot Smith in recent years has written largely on the morphology of this region in mammals and he considers that the fissure is composed of two parts, an anterior, or Intercalary fissure which in man becomes widely separated to form the Calloso-Marginal and a posterior part or true Calcarine fissure which represents the calcarine fissure in man. He calls the whole Sulcus the "Calcarine - Complex".

As regards the homologies between the fissures in these lower mammals and in man there is much difference of opinion.

3. Sir William Turner and the late Professor D.J. Cunningham deny that such homologies exist, while other eminent observers trace a close relationship, such as Ziehen.

4. Campbell in a review of the subject looks for a fissure to homologise with the transverse terminal piece or fissure of Seitz in the human Calcarine

fissure /

II.

fissure and suggests that the Suprasplenia, which is well marked in the dog supplies the need.

Elliot Smith regards the Lateral fissure as the representative of the Intraparietal and as regards the supra-sylvian much difference of opinion exists.

Krueg's account of the development of the fissures in the Ungulate brain will now be discussed.

He states that in an 18 cm sheep foetus there are no fissures (excluding the Rhinic) and that in a 19 cm foetus there are two fissures, one mesially which he calls 'Splenia' and the Sylvian, laterally which however does not directly concern this paper.

In a 24 cm foetus all the principal fissures have appeared and in 27.5 and 30 cm specimens the Ungulate type is fully attained.

The state of development in Krueg's older foeti corresponds closely with the description already given but I think he is certainly wrong in the statement that there are no fissures before the foetus attains a length of 19cms for it has been shown that the Neopallial sulci appear much earlier than that and in a 16 cm foetus both the Splenia and the Lateral are well marked. Probably the differences are due to different hardening methods but as mine were hardened in Formalin in Situ they are presumably correct and moreover I have examined many specimens whilst Krueg admits the difficulty of obtaining material.

In the case of the pig he also places the development of the fissures at a later date and states that a 15 cm foetus shows no furrows and that they develop

between /

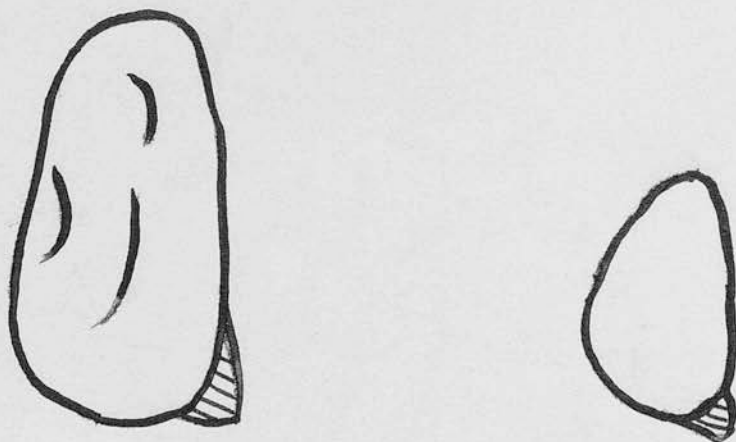
between 18 and 20 cms, some foeti of the same length showing different degrees of development, a feature noticeable in my series.

Finally Krueg gives a comparison of the Ungulates and Carnivora, and states that the 'Haupt-furchen' or most important and most constant sulci appear first, and that there is no trace of transitory furrows and these conclusions are supported by the present series.

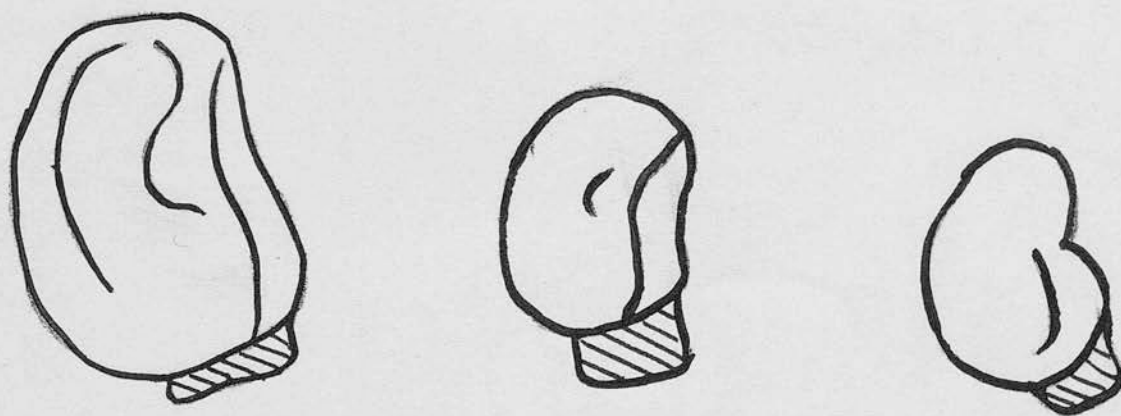
The arrangement of the sulci in these two adult Ungulates corresponds very closely to that in the Carnivora and so far as the region under examination is concerned have been considered at some length in order to avoid any confusion at a later stage, when a full description of the histology of the sheep, pig, dog and cat will be given. The fissures will be named Calcar. Intercalary, Lateral and Rhinic, throughout in the following descriptions.

The above points are illustrated by the following series of Dioptograph tracings.

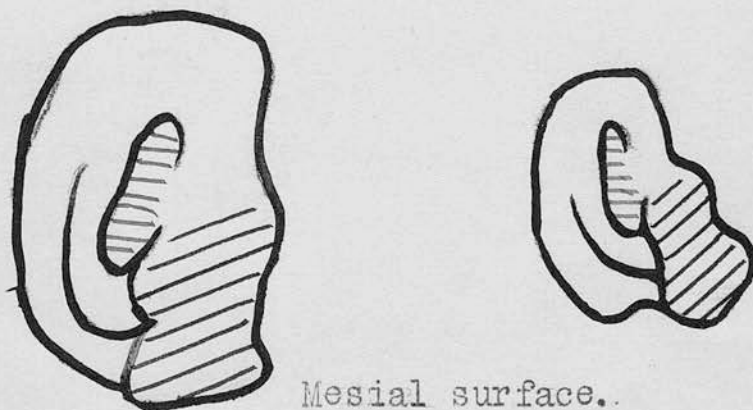
Early stages.



Dorsal-lateral surface.



Lateral surface..

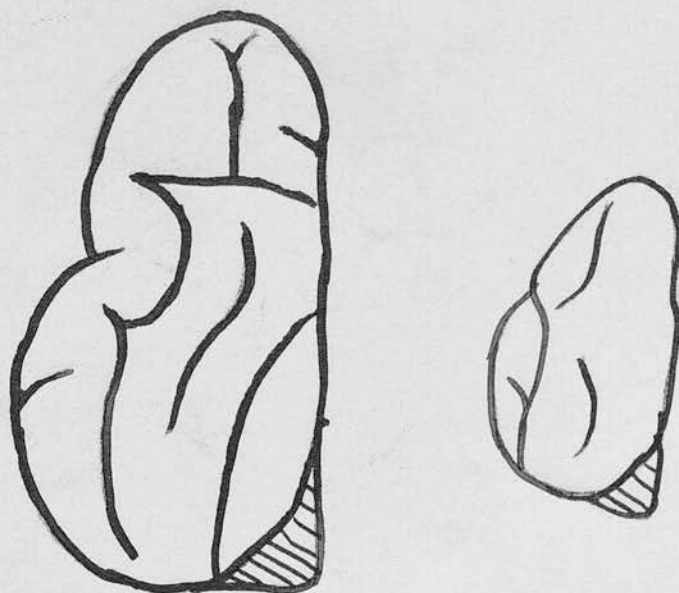


Mesial surface..

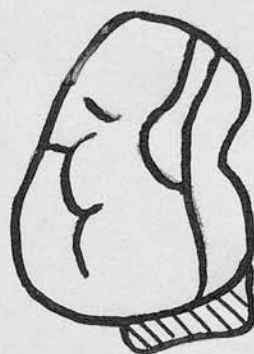
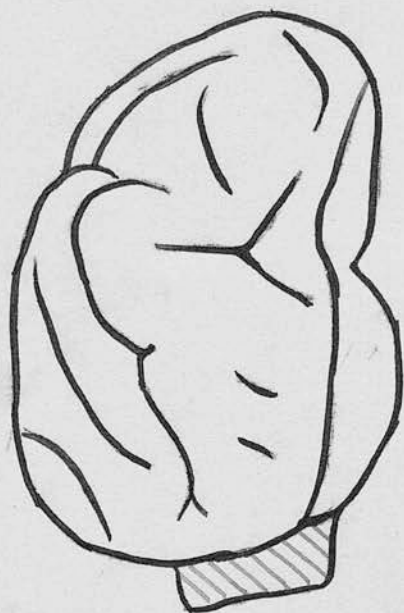
I4-I5 cms..

I2. cms.

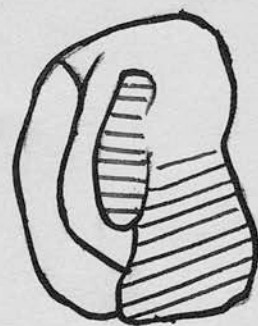
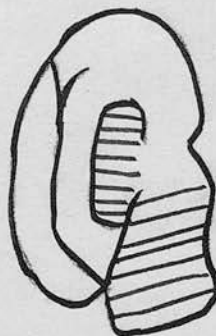
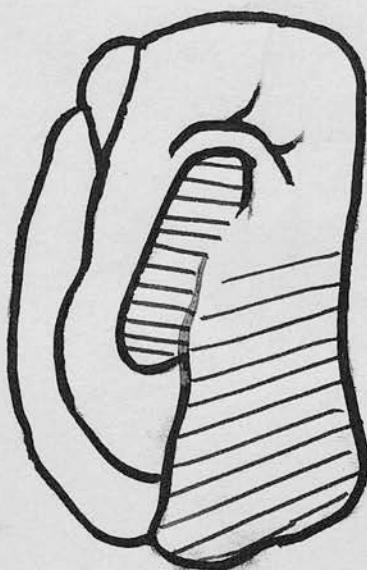
II. cms..



Dorso-lateral.



Lateral.



Mesial.

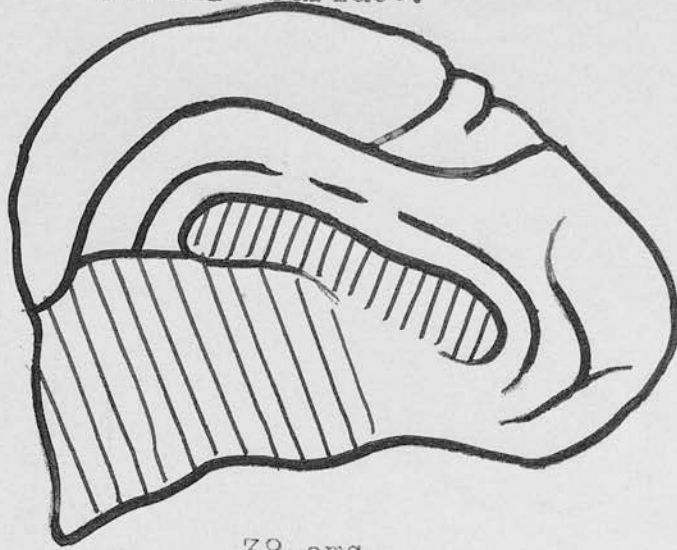
27. cms

22. cms.

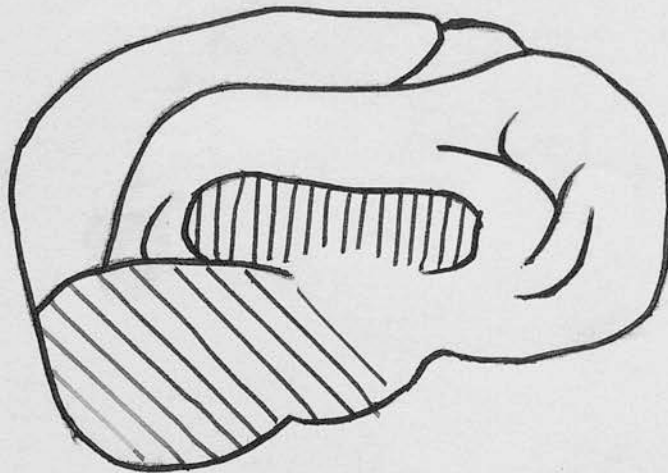
20. cms..

Mesial surface.

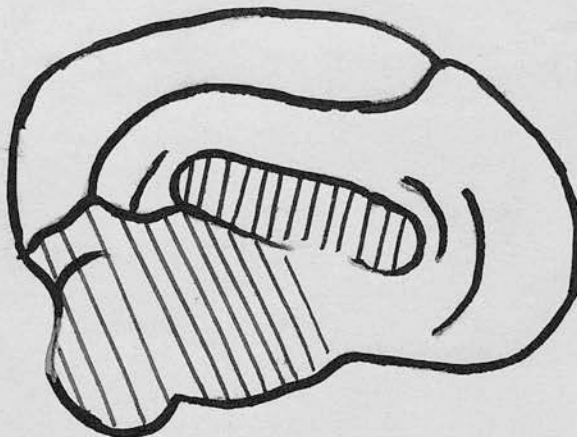
3a.



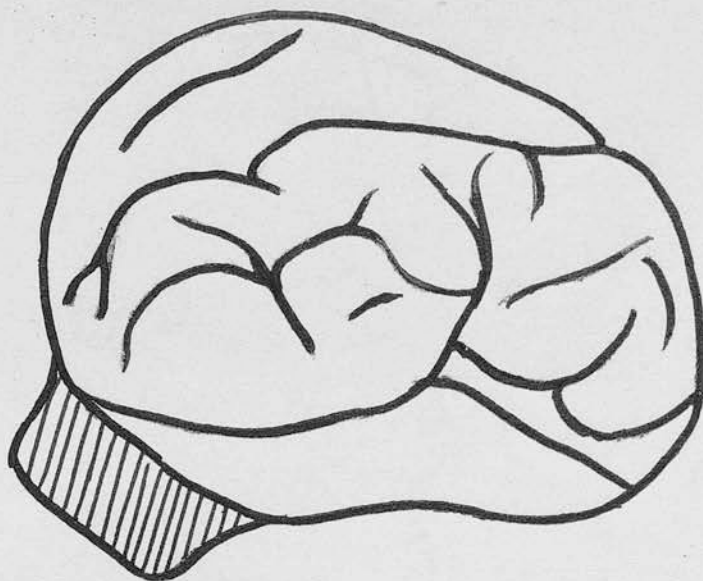
38 cms..



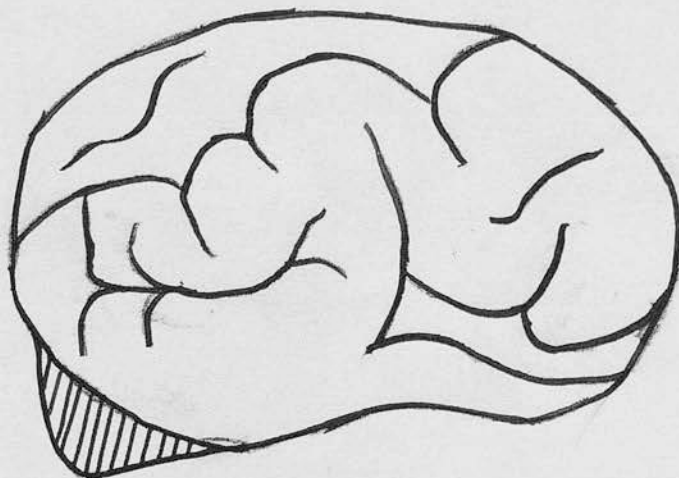
35.5 cms..



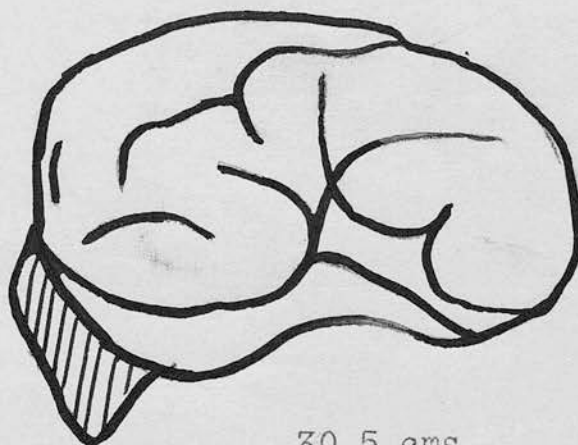
30.5 cms..



38. cms..

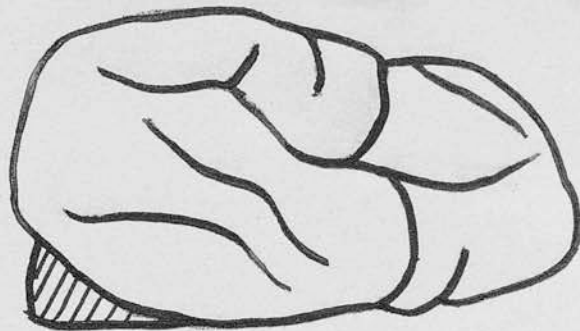


35.5 cms..

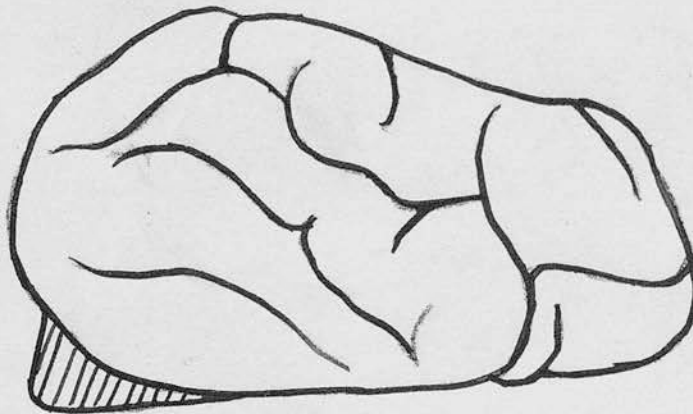


30.5 cms.

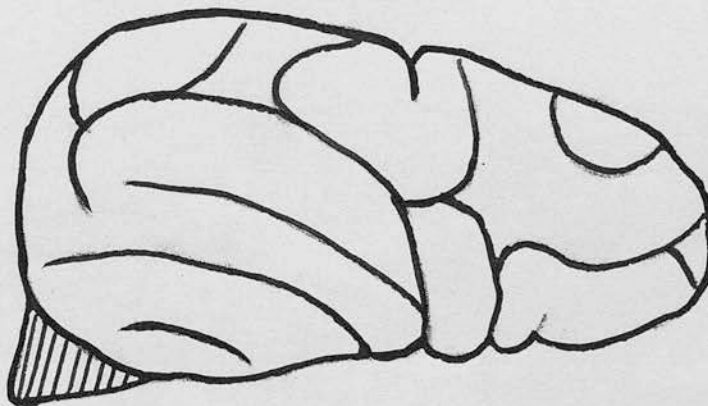
Dorso-lateral surface.



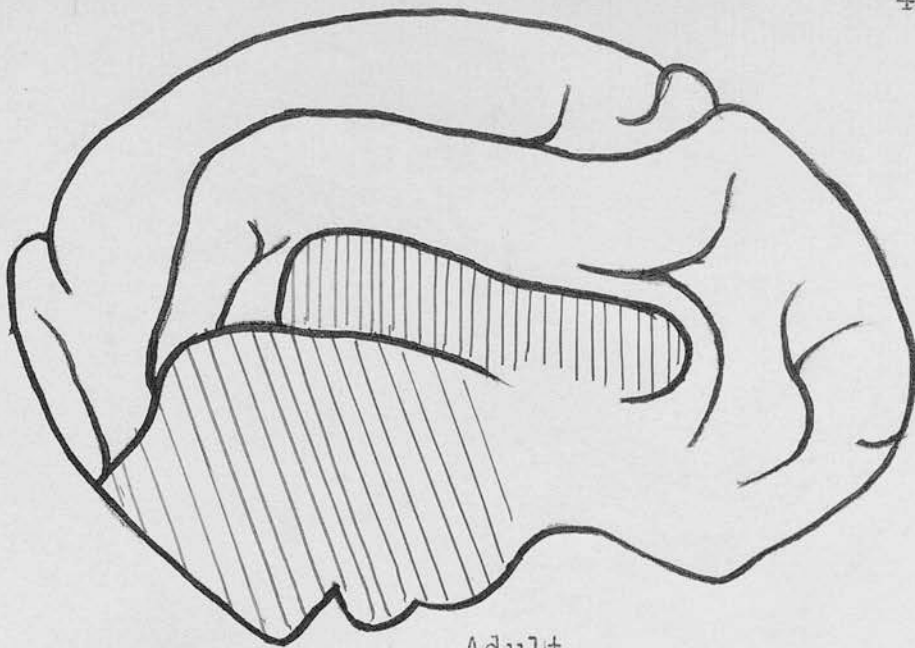
30.5 cms.



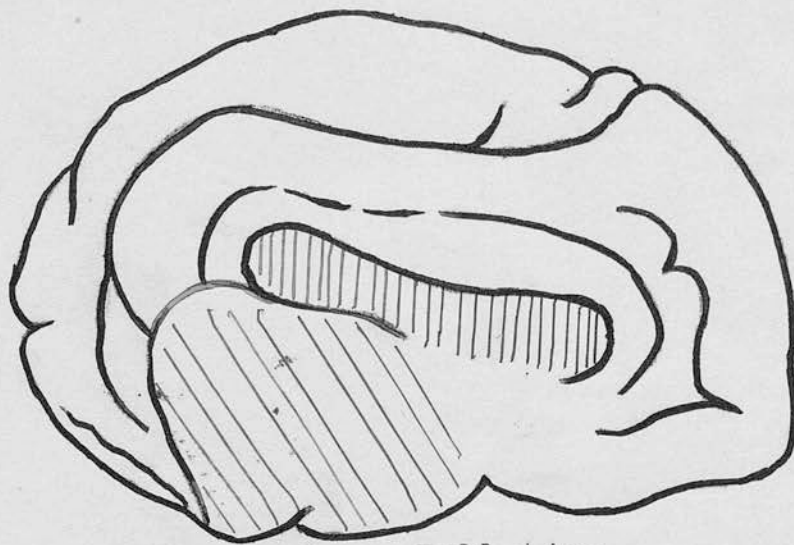
35,5cms.



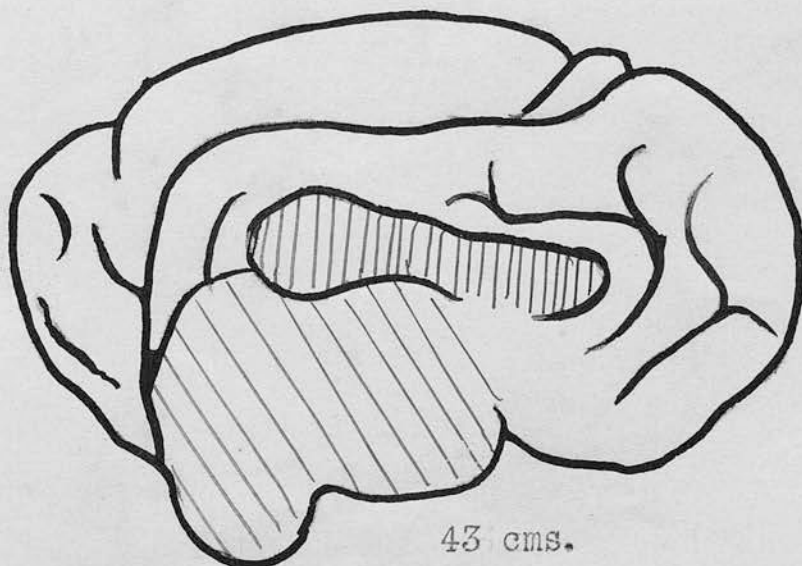
38. cms.



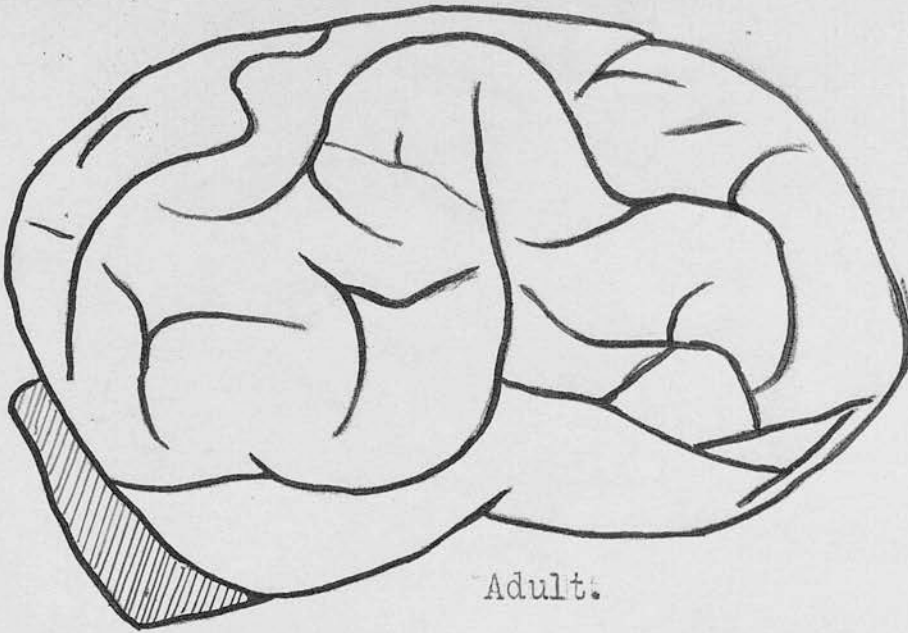
Adult.



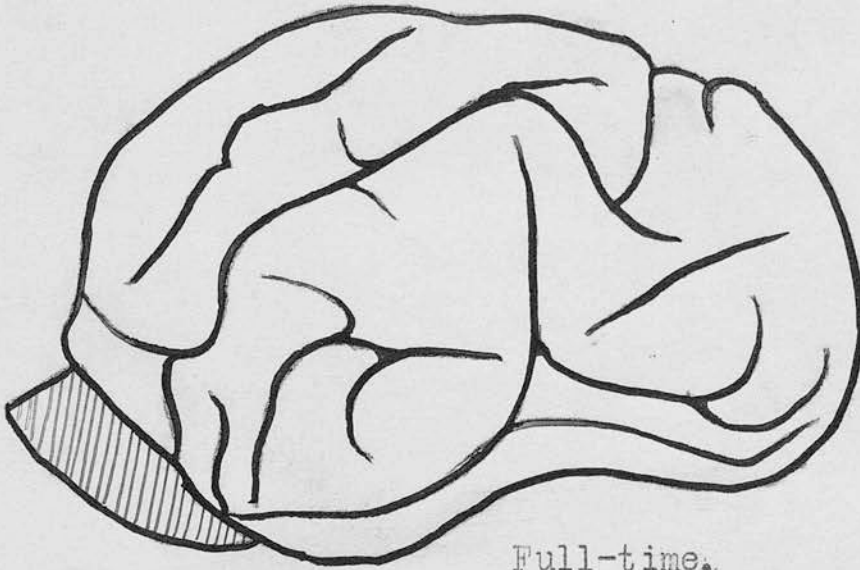
Full-time.



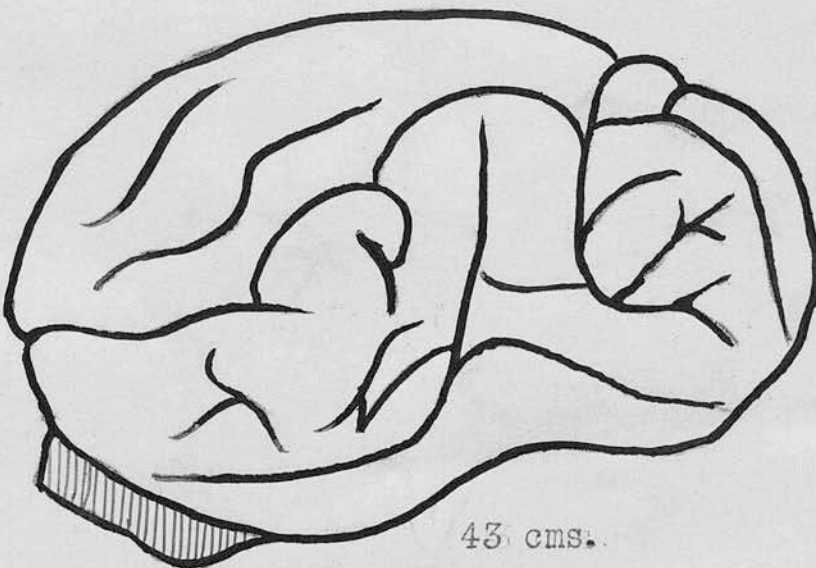
43 cms.



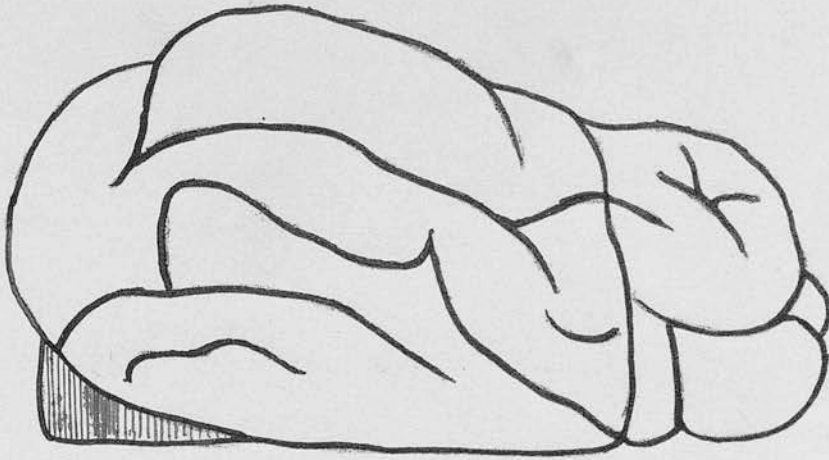
Adult.



Full-time.



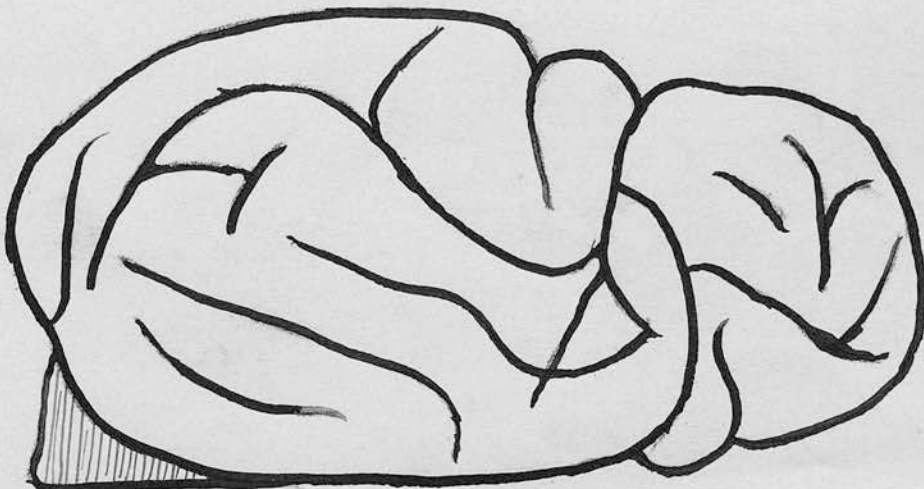
43 cms.



43 cms..



Full-time.



Adult.

Sheep Embryo of 1.5 cms

This has been the youngest embryo available and as the brain structure is extremely primitive it will serve as a good starting point from which to trace the development of this region.

Sections, which pass across the posterior end of the ventricle, show that the structure of the brain wall at this stage corresponds very closely with that given by His for the early neural tube. The brain wall is formed of three layers:-

1. Peripheral reticular layer, narrow, and composed of a coarse reticulum of irregular fibres, with no evident cells, except where it adjoins the subjacent layer.

2. Mantle or Cellular layer, which forms the greater part of the brain wall. It is composed of very numerous, densely packed young nerve cells, in which mitotic changes are going on vigorously. Many of the cells are still rounded, whilst others are pyriform neuroblasts with a short apical process and all stain deeply and have prominent nuclei and nucleoli.

This cellular layer is of great importance and will be seen to undergo various changes in the later members of the series.

3. Ependymal layer, which surrounds the ventricle. This consists of tall columnar cells with nuclei set at different levels. Internally they are separated from the ventricular cavity by a well defined internal limiting membrane, whilst externally they pass outwards amongst/

amongst the deeper cells of the mantle layer. Scattered through this layer, especially near the ventricle, there are large round cells, showing mitosis very clearly. These are the germinal cells or "Keimzellen" of His.

Mitosis is evidently going on very actively at this stage and the figures are well seen especially in the germinal cells of the Ependymal layer.

The brain wall at first is of about equal thickness on both surfaces, but the inner soon becomes considerably thinner as the sections pass forwards.

In an Embryo of 2.5 cms. there are certain slight advances.

The Mantle layer shows signs of becoming divided and the outer cells are much less closely packed than the inner and may be regarded as a separate layer.

In the more anterior sections, there is some evidence of the formation of a Peripheral layer of scanty cells especially on the lateral surface but it can hardly be regarded as a separate stratum.

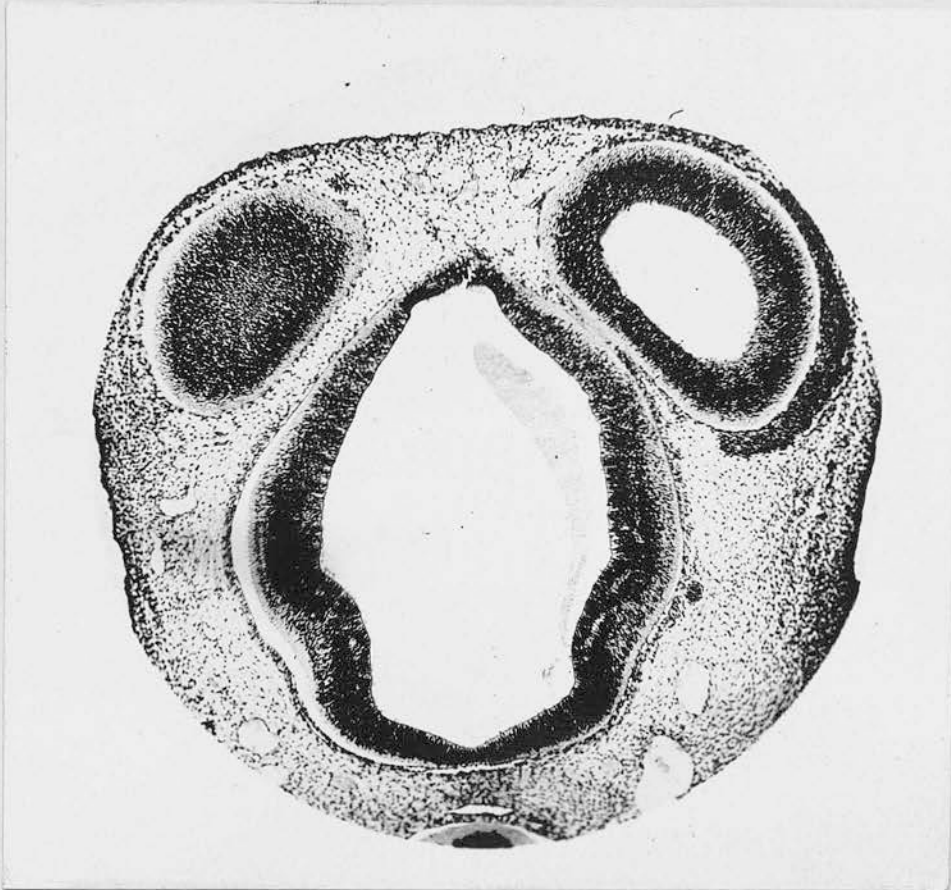
The overlying peripheral reticular layer now contains cells and its reticulum is coarser.

The difference in thickness of the mesial vertical & lateral wall is maintained.

An Embryo of 4 cms. shows a very definite advance, for the mantle layer described above has become subdivided/

SHEEP. 2 cms.

X 54.

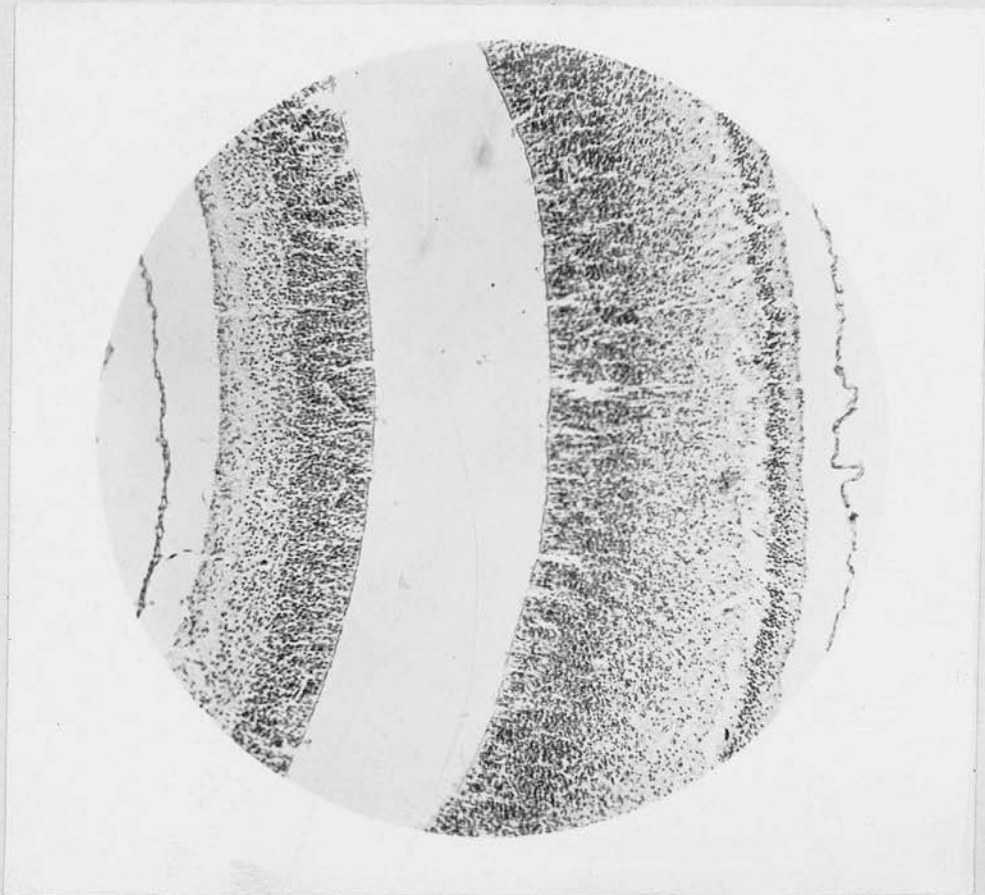


NOTE.

1. Peripheral reticular layer.
2. Cellular layer.
3. Ependymal layer.

SHEEP, 4 cms.

X 93.



NOTE.

1. Differentiation of brain wall well advanced.
2. Peripheral cortical cell layer split off
Mantle layer in the lateral wall.
3. The different depth of the two walls.

subdivided into: -

(1) An important peripheral layer of cells which represents the earliest stage of the adult cortical layers, and which along with the peripheral reticular layer constitutes the cortex at this stage. This layer will gradually be seen to increase in depth and complexity in later members of the series.

(2) A deep layer of cells which is capable of subdivision into secondary layers at first, and surrounds the Ependymal Epithelium. This layer, the deepest portion of the original mantle layer, will be seen gradually to lessen in importance in older Embryos.

These two cellular layers are separated by a fairly wide clear reticular area which evidently corresponds to the adult white or medullary centre.

Henceforth the changes will be described under the following heads viz:- Cortex which includes the peripheral reticular layer of the Embryo which will now be called molecular or plexiform layer, and the cell layer or layers beneath it: white centre: cellular layers surrounding the ependymal epithelium: and lastly the ependyma.

Early Sections across the extremity of the occipital lobe show a marked difference in structure on the two surfaces of the hemisphere for the cortical cell layer is much more prominent laterally whilst mesially the cells forming it are extremely scanty. On both surfaces it is much more definite in the upper half of the hemisphere

Later /

Later Sections across the hinder end of the ventricle show still further differences between the two walls of the brain, the inner being much the narrower.

Laterally the cortex consists of the following layers :-

1. Molecular, not very broad, containing a number of cells, of which the outer are larger and scantier.
2. Prominent layer of dark stained cells with rounded nuclei and indistinct bodies. The cells are several deep and the layer is best marked in the upper part of the hemisphere and gradually becomes less distinct below,

The white centre is broad and is formed of a reticulum of fibres containing scattered cells

The cellular layer around the ventricle is divided into an outer broad band of large oval or fusiform cells set mostly parallel to the surface and lying next the medullary centre, and a deep inner layer of pyriform neuroblasts set vertically.

The Ependymal Epithelium consists of tall columnar cells lying upon a very distinct internal limiting membrane and extending outwards amongst the cells of the previous layer.

Mesially the principal differences are :-

1. Reduction in depth of brain wall largely at the expense of the white centre.
2. The prominent cortical cell layer is much less developed and its cells are very scanty.
3. The layer of deep circumferential cells is much narrower.

The lower part of the hemisphere presents a special structure even at this stage. As noted above the prominent cortical layer of cells gradually narrows below and towards the lower border the cells become much fewer and are more scattered presenting a marked contrast with the outstanding layer seen above. At the same time the cellular layers around the ventricle become thickened opposite its lower pole and form an oval mass which projects into the ventricular cavity, thus indicating the early formation of the Basal Ganglia. These differences between the upper and lower portions of the hemisphere probably mark the limit between the Rhinencephalon and Neopallium and become more definite in more anterior sections.

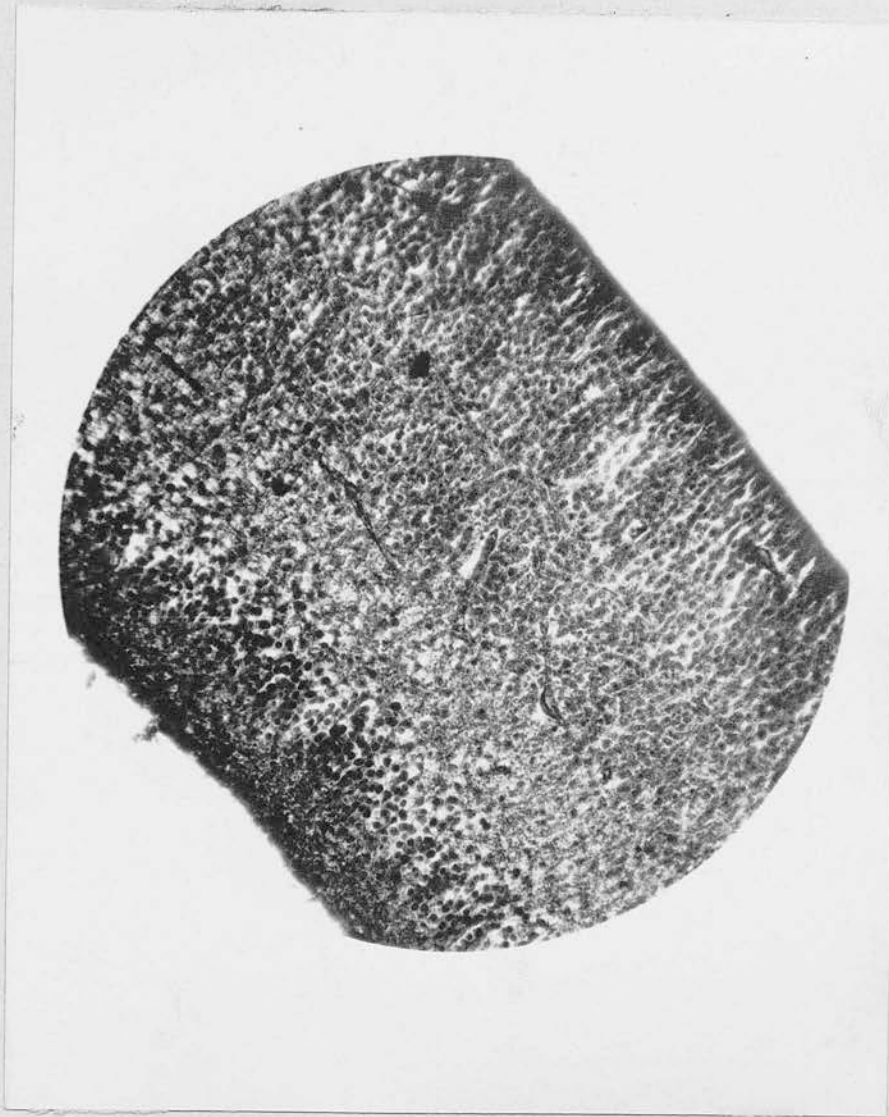
An Embryo of 5.5 cms. shows a distinct advance, notably an increase in depth of the cortical cell layers and a relative reduction of the cells around the ventricle. Thus, on the mesial surface the very scanty cortical layer seen in the previous embryo has become a prominent layer of large cells several deep, closely packed together. The general features previously described still hold but the neuroglia appears to be much more abundant and stains darkly in Cajal preparations.

An Embryo of 6.5 cms. shows similar advances but does not call for any special description. The cells are gradually becoming more definitely angular in place of being pyriform or rounded.

An Embryo of 7.5 cms. shows that all these changes have advanced /

SHEEP, 6 cms. X 172.

Lateral wall.



NOTE.

1. Commencing differentiation of brain wall.
2. Peripheral cortical cell layer split off from Mantle layer.
3. Ependymal cells well seen.

advanced very markedly , the cortex becoming more prominent, the cellular layers around the ventricle being reduced and the Ependymal Epithelium becoming shorter.

An Embryo of 8.5 cms. Early sections from near the tip of the occipital lobe show that the Cortical structure is practically the same in both surfaces of the hemisphere.

Later sections across the hinder end of the ventricle show that the most striking feature is the great development of the Cortical cell layer. It has become very deep on both surfaces and the cells have also advanced very markedly and are coming to approach more closely to the adult angular type from the early neuroblastic stage.

Mesially it forms a very characteristic layer of large cells set mostly vertically and the growth of this layer has been very striking.

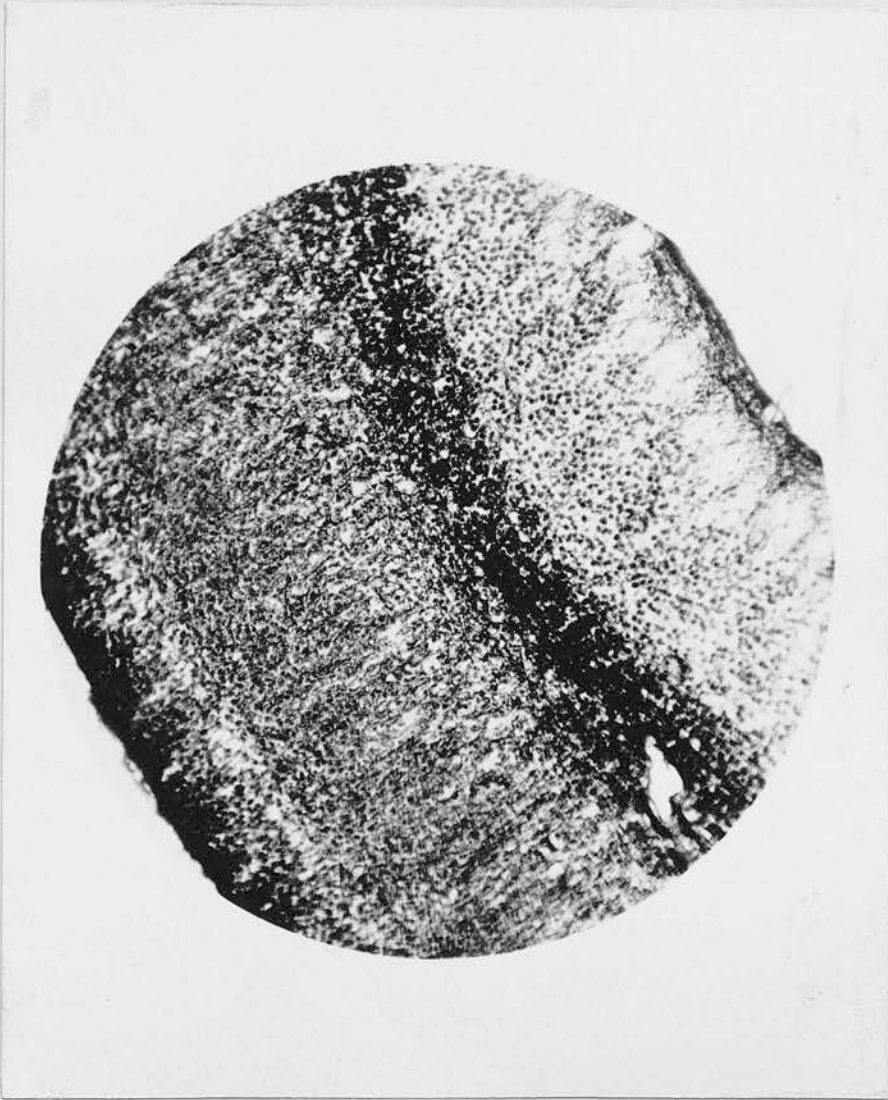
Laterally in its middle portion the layer shows signs of becoming divided into two by the appearance of a slight opener layer in its outer part.

The cell layers surrounding the ventricle have become still further reduced.

The lower portion of the hemisphere has become more clearly demarcated from the upper, and will be described

SHEEP, X 134, 8.5 cms.

Mesial wall.



NOTE.

1. Brain wall further differentiated.
2. Cortical cell layer well marked.
3. Reduction of Ependymal layer and of the cellular layers around it.

in detail in the next specimen.

In a foetus of 10 cms. Early sections show that the original single cortical cell layer lying between the molecular layer and the white centre has in a great part become split into two very definite layers by the appearance of a fairly clear reticular area in its outer part. The outer of these two layers is the narrower, and in the greater part of the hemisphere they are quite distinct but towards the upper border, the cells generally are increased and the two layers are more or less fused, whilst towards the lower border they are tapered off.

Later sections across the ventricle give fuller details of the advances.

Mesially the cortex consists of the following layers :

1. Molecular layer which is broader and contains more abundant cells which are disposed in two quite distinct layers; an outer formed of larger cells with big oval or rounded nuclei, which stain faintly, (Meynerts corpuscles;) and an inner in which the cells are more numerous and have small round deeply stained nuclei. These cells are supported by an abundant reticulum.
2. Layer of closely packed small and medium sized angular cells mostly of a pyramidal type and mostly set vertically.
3. Reticular layer, quite open at first and containing very few cells, but later the cells increase very greatly. They are mostly small with occasional large scattered /

scattered cells.

4. A broad layer of cells similar to the outer but more numerous and more thickly packed.

At first the cellular layers mesially are of about equal thickness in their whole extent but they soon become tapered off below and the two layers become fused near the lower border of the hemisphere. Above the cellular layers become more condensed towards the upper border and finally turn round it to become continuous with the thick upper part of the lateral cortex. The further forwards the sections pass the more evident does this narrowing below of the cellular layers become and it appears to result from a suppression of the deeper layer which is perhaps of less importance.

Later sections show that another element is added to the lower aspect of mesial surface for an elongated and apparently separate mass of cells appears here in rather more than its lower third. It is a hook-like process formed of numerous large angular cells supported by a plentiful reticulum and surrounded by a molecular layer of its own by means of which it is fused to the molecular layer of the mesial brain surface. Later sections show that this apparently super-added portion is simply a terminal recurved expansion of the lower end of the important well developed and deeply stained cell layer traced forwards upon the mesial surface. This recurved cell mass is placed a little below the centre of the hemisphere and from here to the lower border the structure of the

whole /

SHEEP. 11 cms. X 83.

Nissl.

Mesial wall.



NOTE.

1. Brain wall well differentiated.
2. At this stage differentiation is better seen mesially than laterally.

whole thickness of the brain wall appears to be the same for the broad molecular layer present above becomes merged into the under-lying cortex and there is no subdivision into layers. The peripheral cells are slightly larger, and the deepest cells near the ventricle are not so plentiful. This structureless area gradually becomes thinned and interrupted to form the choroidal fissure.

The Medullary centre is fairly broad and is composed of fibres and numerous small cells.

The cells around the ventricle have become much reduced and form two layers with an open layer between them. Later sections show that the outer of these layers becomes lost or it extends downwards.

The Ependymal Epithelium has become much shorter and the internal limiting membrane is very distinct.

Laterally, the cortex can be divided into the following layers :-

1. Molecular, as before.
2. Outer thin layer of pyramidal cells of fairly uniform size.
3. Reticular layer containing many small rounded cells.
4. Inner and broader layer of pyramidal and rounded cells.

This subdivision of the cellular layers is very distinct in the lower part of the hemisphere but towards the

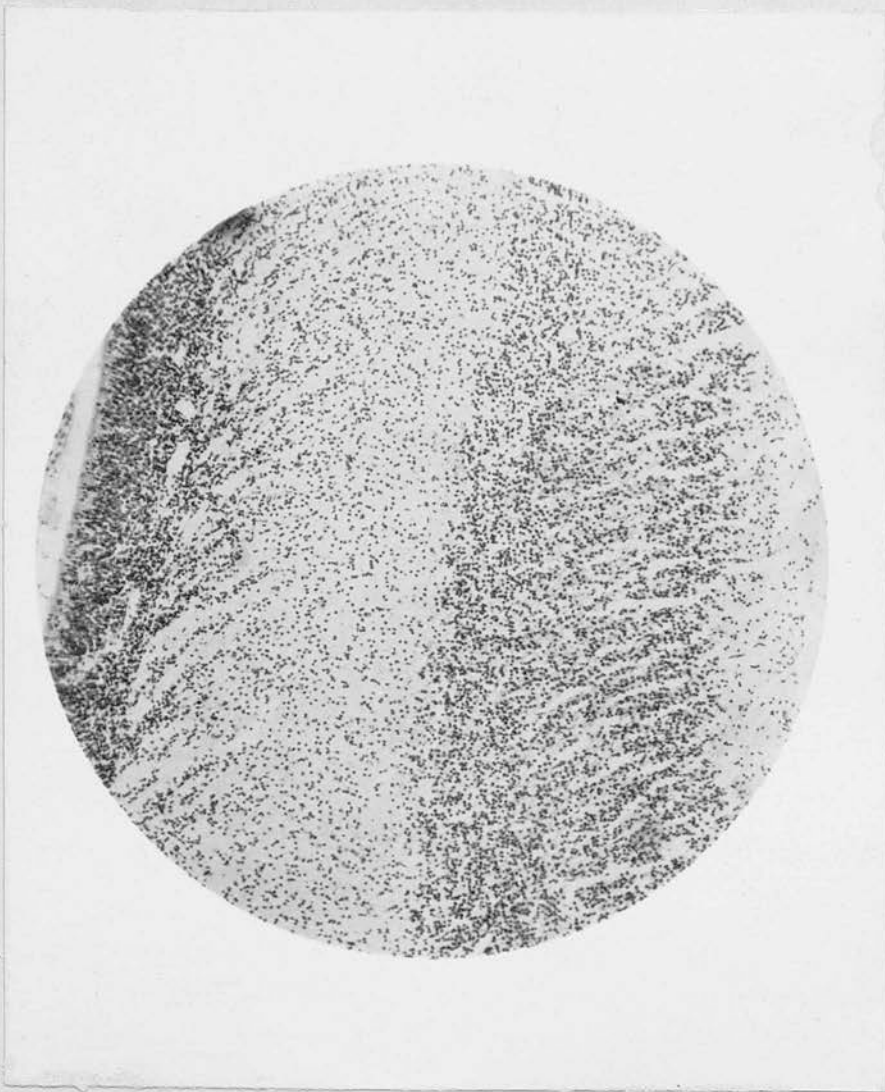
upper /

SHEEP, X 83.

11. cms.

Nissl,

Lateral wall.



NOTE.

1. Brain wall further differentiated.
2. Cortical layer deep.
3. Remains of Mantle layer around Ventricle
much reduced.

22

upper border, the layers fuse to a great extent, and the cells are more abundant and more closely packed. At the superior border too the prominent cell layer is thickened where it meets the thick upper end of the mesial cortex.

The Rhinic Area.

In the lower third of the hemisphere, the cellular layers become much thinned and this area possesses a distinctive structure.

1. The Molecular layer is broader and contains fewer cells except around the lower border.
2. The outer cell layer becomes irregular and the cells show a marked tendency to be arranged in clumps or clusters, thus giving an irregular outline to the area.
3. The inner cell layer gradually fades away until it meets the mesial cortex at the lower border.

The White centre is broad and contains scattered cells which in more anterior sections tend to be aggregated together about the middle of the area to form an extra, narrow layer of loosely packed small cells.

The cells around the ventricle form two well marked layers broader than on the mesial surface and thickened at the upper and lower ends of the ventricle. The deeper layer around the ependyma contains larger and more fully developed cells than the outer.

In a foetus of 12 cms the principal advances consist in a thickening of the cortical cell layers specially, and a further development of the cells themselves for they have become bigger and their processes are more evident.

The thickening of the cortex near the upper border on the mesial surface and is well marked and should be noted specially for it is in this situation that the Calcarine-intercalary fissure is to appear.

Cajal preparations show that there has been a great development of the neuroglia which is most abundant and stains most darkly in the cortical area.

The cellular layers around the ventricle have become much reduced mesially especially in the more anterior sections, whilst laterally they gradually become comparatively increased.

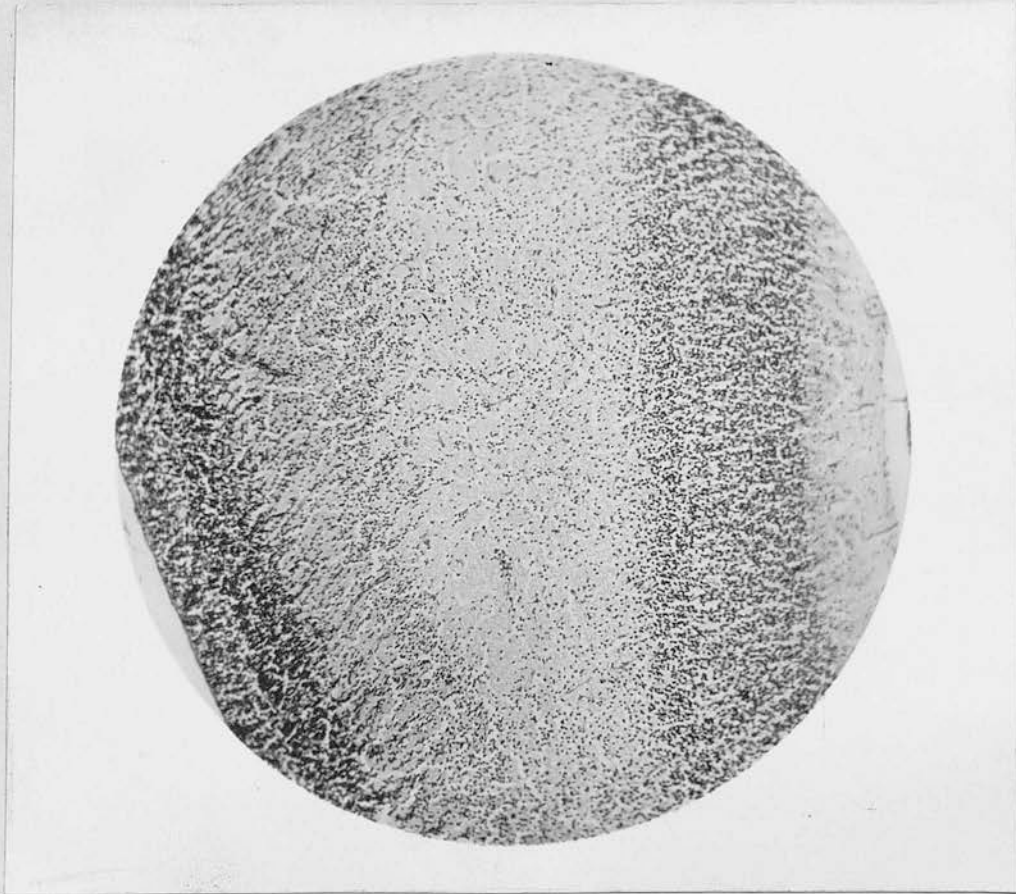
In a foetus of 13 cms further advances have taken place in the direction of an increase in thickness of the cortical cell layers and a further development of the cells themselves or their processes are much more distinct especially in the cortex on the mesial surface, where the cells are particularly prominent. Later sections show that another change gradually occurs in the mesial aspect, for the cortex ends above and below in a recurved expansion and these are separated by an intermediate area in which the brain wall consists simply of an expanded molecular layer

and /

SHEEP, 13 cms. X 70.

Nissl.

Mesial wall.



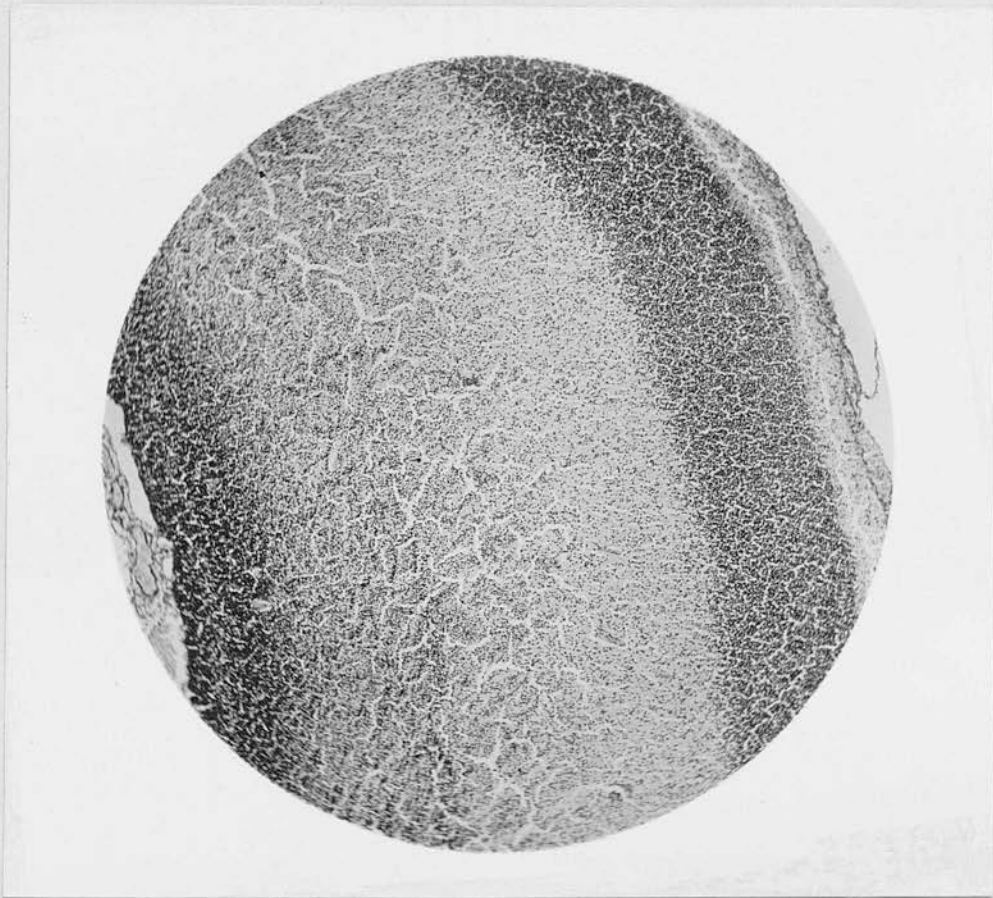
NOTE.

1. Differentiation of brain wall far advanced.
2. Cellular cortex relatively deep, showing signs of subdivision into layers.

SHEEP, 13 cms. X 71.

Nissl.

Lateral wall.



NOTE.

1. Broad but as yet undifferentiated cortical layers.
2. Great reduction of the cell layers around Ventricle.
3. Broad Medullary centre.

and the ependymal epithelium with a narrow layer of cells outside it.

Still later sections that this intermediate structureless area is gradually reduced and finally becomes invaginated into the ventricle in the formation of the Choroid Plexus.

The upper thickened portion of the mesial cortex which is to lie around the Calcarine-Intercalary fissure is now very prominent and the upper ends of the two hemispheres become flattened and are closely opposed to one another, thus pushing the mid-brain to a deeper level and coming to roof it over completely. As yet no fissure is visible in this area but the cortex is thickened and dips down into the deeper parts in what is evidently to be the site of the Calcarine Intercalary fissure.

The cells about the middle of the white centre are condensed to form a loose layer between the cortex and the grey matter round the ventricle and this latter has become greatly reduced mesially.

The Rhinc fissure is faintly marked and indicates an alteration in structure of the cortex; that below it showing a more primitive condition than the Neopallic cortex above.

In a foetus of 16 cms. the early sections near the tip of the occipital lobe show still further differentiation and both surfaces of the hemisphere possess two prominent cortical cell layers, outer narrow and inner

broader /

broadier which lie between the Molecular layer and the Medullary centre.

Later Sections display further advances, the cortex becomes much deeper, and the structure is more complicated owing to the appearance of fissures. The first of these to appear is the posterior end of that deep and well-marked fissure which separates the Rhinencephalic area from the Neopallium and is called the Rhinic fissure.

On the Mesial surface the upper part of the cortex is divided into the following layers :-

1. Molecular layer which is much deeper and has its two layers of cells much better defined.
2. Outer layer of small and medium sized angular or stellated cells with very evident processes. The smaller cells lie next the molecular layer but the two sets mingle very closely.
3. Broad opener reticular layer in which the cells are less abundant and are smaller. In one area viz : - the cortex of the apposed medial surfaces there is some evidence of the development of some large pale scattered cells in the deeper part of this layer but it cannot be traced as a distinct stratum. The reticular frame-work of this layer is more plentiful than in the adjacent parts.
4. Broad layer of small or medium irregular angular or rounded cells lie next the white centre.

Later Sections show the gradual appearance of a fissure in the upper part of the mesial surface of the hemisphere and this is the early Calcarine Intercalary fissure /

fissure or splenial complex. The thickened cortex in the region dips down to line the walls of this fissure, is somewhat reduced in width but is still plainly divisible into the layers described above, and emerges above to become continuous with the cortex in the lateral surface. The fissure gradually deepens in the more anterior sections and comes to lie more upon the mesial surface and these later sections show that the cortex lining its lower aspect is thicker than that in the upper.

The lower part of the mesial cortex gradually becomes reduced in width and still more anterior sections show that it finally becomes divided into upper and lower portions, each terminating in a prominent and expansion, whilst the intermediate area is thinned until it becomes invaginated into the ventricle in the formation of the Choroidal Fissure.

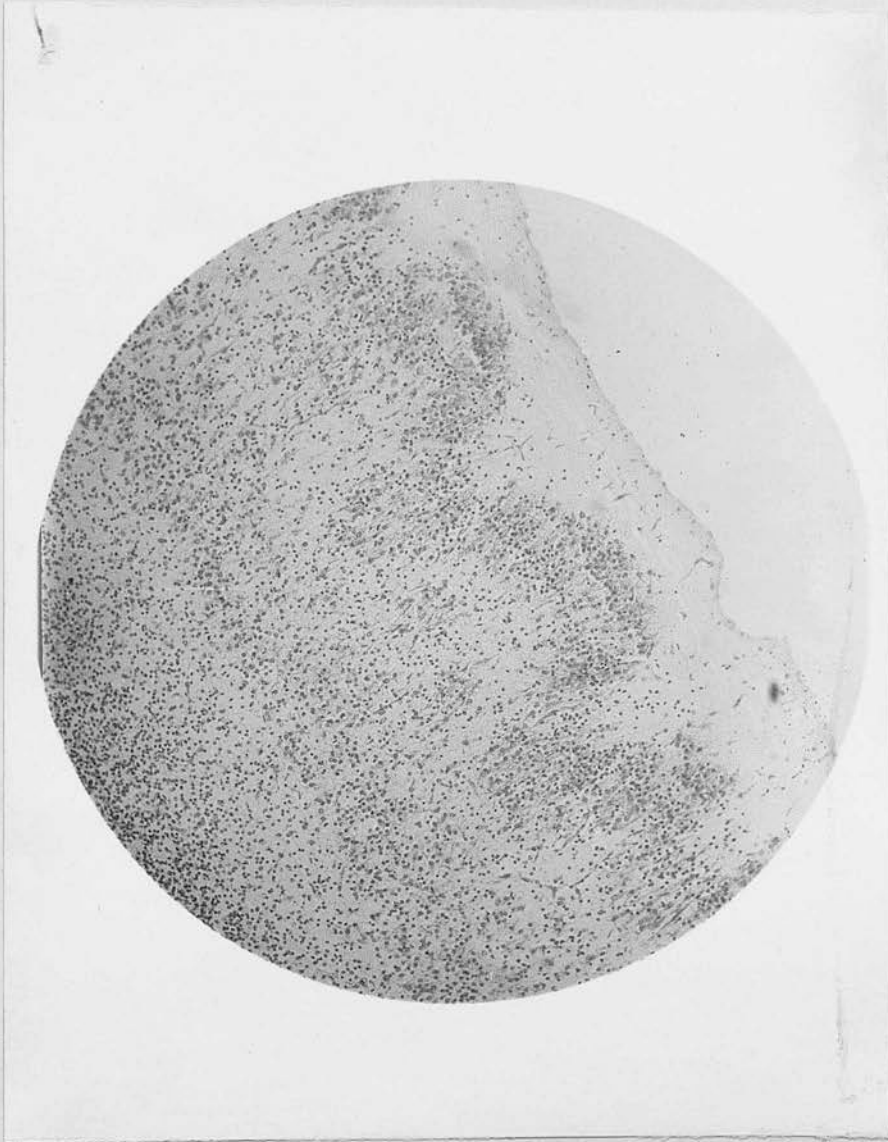
On the Lateral Surface definite changes are seen as the sections pass forwards. The lateral fissure is faintly marked near the upper border of the hemisphere and near the lower the posterior end of the Rhinic fissure makes a deep indentation and divides the outer surface into a small lower and a large upper part.

I. The Cortex of the upper or Neopallid part presents the same general structure already noted and does not require detailed description.

II. The cortex of the lower or Rhinic area presents a sudden and a marked change in type but corresponds fairly closely with the description of the same area in the previous embryo. The earlier sections show that there/

SHEEP, about 16 cms.

Rhine Area.



NOTE.

1. Deep and clear Molecular layer.
2. Irregular outline of superficial cell layer.
3. Clustered arrangement of cells in it.

there are an inner and outer cellular band separated by an intermediate reticular layer containing a fair number of cells, but later sections indicate that the inner cell layer gradually becomes reduced and ceases to exist as a definite layer. The cortex of the Rhinic area hence is more primitive than the rest and consists of a molecular layer and a single layer of cells set upon a broad medullary centre rich in cells, some being of large size.

The limit between these two types of cortex is extremely well marked.

In general, the deeper structure of the brain wall at this stage remains much the same.

The Medullary centre still shows a condensation of cells to form an indefinite layer between cortex and ventricle.

The cellular layers around the ventricle, laterally become increased especially towards the lower pole of the ventricle and in sections far forwards come to form a thick oval mass of cells indicating the Basal Ganglia. Mesially however the grey matter though plentiful at first soon becomes reduced to a single or double row of cells outside the Ependyma.

The Ependymal Epithelium has become reduced to a layer of short columnar or cuboidal cells.

A foetus of 20 cms shows very definite advances.

In early sections from near the tip of the occipital lobe the structure appears to be essentially the same

In both surfaces of the hemisphere, and a detailed description will be given from later sections where the structure has become still more definite.

As the sections advance into the lobe three fissures gradually come into view the Calcarine Intercalary in the mesial surface, which is much deeper and lies at a lower level than in the previous embryo, and the posterior ends of the Lateral and Rhinic fissures in the lateral surface, the one near the upper and the other near the lower border. At the same time the cortex is deeper and its subdivision into layers very distinct showing that this foetus has attained a high degree of development.

On the mesial surface the cortex is at first of about equal depth in its whole extent but it soon becomes reduced in its lower part and finally with the appearance of the Corpus Callosum becomes separated into two distinct parts:—

1. Upper which forms the true mesial surface, and extends from the Corpus Callosum to the superomesial border of the hemisphere. It is deeply indented about its centre by the Calcarine Intercalary sulcus and possesses the same general structure as the lateral cortex.
2. Lower which is closely applied to the mid-brain below the commissure. It soon becomes greatly thinned and the cell layers are reduced to form a prominent band lying near the ventricle which consists of an outer set of medium sized angular cells and a deeper

layer /

layer of very large erect pyramidal cells. This prominent cellular layer belongs to the cornu ammonis and finally becomes interrupted below to admit the choroid plexus into the ventricle.

On the Lateral Surface the cortex appears to possess the same structure and minor differences down to the Rhinic fissure at which a sudden change occurs. Hence there is a wide extent of cortex extending from just below the Calcarine-Intercalary to the Rhinic fissure of essentially similar nature.

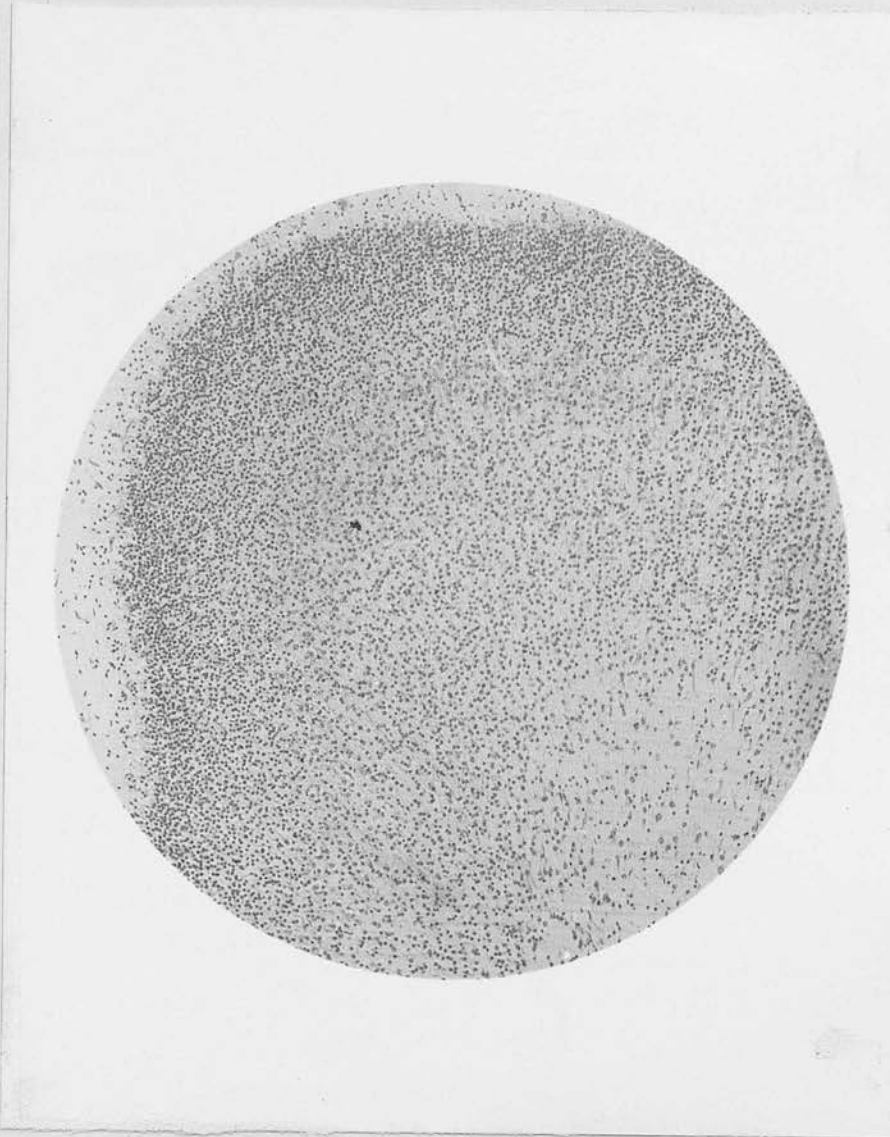
General type of cell lamination :-

1. Molecular layer of considerable depth showing an outer layer of scanty large pale cells lying close to the surface and a deep layer of numerous small round darkly stained cells placed close to the next layer.
2. Layer of small and medium sized angular cells, closely packed and possessing abundant Nissl granules. This layer evidently corresponds to the original cortical layer seen in the youngest embryos.
3. Reticular layer with more abundant reticulum containing numerous smaller angular cells. This layer is of about the same depth as (2).
4. Layer of large pale highly developed cells multipolar or pyramidal which are set mostly vertically and possess large pale oval or round nuclei and very abundant Nissl granules. These cells make up a fairly broad layer, which is a very prominent feature of the cortex at this stage.
5. Layer of small oval fusiform or angular cells

variable /

SHEEP, about 20 cms.

Marginal gyrus.



NOTE.

1. Defferentiation of Cortex into layers now well marked..
2. Prominent superficial & deep smallled-celled layer
3. Intermediate layer of large pale cells.

variable in extent in different parts of the cortex, lying upon and merging into the white centre. In the main it forms a broad layer but is much reduced in the fissures and here many of its cells are set parallel to the surface. The cortex generally is thinned at the bottom of the fissures, and it appears to be slightly deeper in that area lying between the Lateral and Rhinic fissures but with these minor differences it is the same throughout.

Rhine Area extends from the Rhine fissure to the lower border of the hemisphere and its structure is modified as follows :-

1. The Molecular layer is deep and contains very few cells.
2. The outer cellular layer presents a very wavy outline and the cells tend to form clusters. The smaller cells of the Neopallid area are largely replaced by an extension of the deeper large cells outwards into it and these large cells come to predominate in this region.
3. A broad clearer area lies beneath this with a more abundant reticulum through which large pale angular cells are scattered.
4. An indefinite layer of smaller cells lies near the ventricular grey matter.

The Cellular layers around the ventricle soon become reduced to a single or double layer of cells on its mesial surface, but laterally they are still abundant, especially /

especially in the lower part and the largest cells are placed deeply.

The Ependymal Epithelium now consists of columnar cuboidal cells, those lining the mesial wall of the ventricle being mostly cuboidal.

Foetl of 27 and 30 cms. The appearance of the section becomes more complicated owing to the increase in depth of the principal sulci and the appearance between them of some shallow subsidiary furrows. The general structure, however, remains very similar to that already described and the cell lamination of the cortex is the same though the layers have become still more definite.

The same general changes occur upon the mesial surface and the cortex at first very similar to that in the lateral aspect soon becomes reduced as described.

The Neopallid Cortex which extends from the level of the corpus callosum to the Rhinic fissure appears to be of essentially the same type throughout and consists of five or six cell layers according as the outer layer of pyramidal cells is divided into an outer band of small and an inner of medium pyramids and this distinction is now well marked.

It may be noted, however, that the depth of the cortex varies a little in different areas and it is thinned at the bottom of the sulci and at the convexity of the gyri. The cell layers, generally, are reduced at the

bottom of the furrows and the deepest layer tends to have its cells arranged parallel to the surface. The deep layer of large pale pyramidal cells appears to be specially thick along the lower lip of the Intercalary fissure and below ~~the~~ point the whole cortex undergoes gradual reduction and the cell layers tend to fuse.

The Rhinic area maintains the differences already described and consists of three layers of cells beneath a very deep and clear molecular layer. The outer layer of cells is very wavy and the clustered arrangement noted before is very marked at the convexity of the region while on either side the cortex comes to resemble the general type.

Both lips of the Intercalary fissure are lined by cortex of the Neopallid type but very soon that on the lower aspect becomes modified. Large pale cells similar to those of the fifth layer in ^{the} rest of the cortex come to predominate in this area and extend outwards among the small medium pyramids which are much reduced.

The Ependymal Epithelium has become still more cuboidal and the grey matter outside it is practically absent on the mesial surface though there is still a little in the outer aspect which is increased at the upper and lower poles of the ventricle.

The Cells generally have become further developed and are mostly angular or pyramidal in type with well marked

processes /

processes which stain better than in previous embryos.

Foeti of 35, 37.5, 42.5 and 47.5 cms have been examined and complete the foetal series as the 47.5 embryo has reached full-time. These older specimens resemble one another so closely and are so very similar to the previous embryo and to the adult sheep that a separate description is not required. There are of course minor differences and the cells in the full-time foetus are better developed than in the younger specimens and are very like those seen in the adult. It is noticeable that Cajal preparations become steadily more successful as the age advances and the processes stain much better.

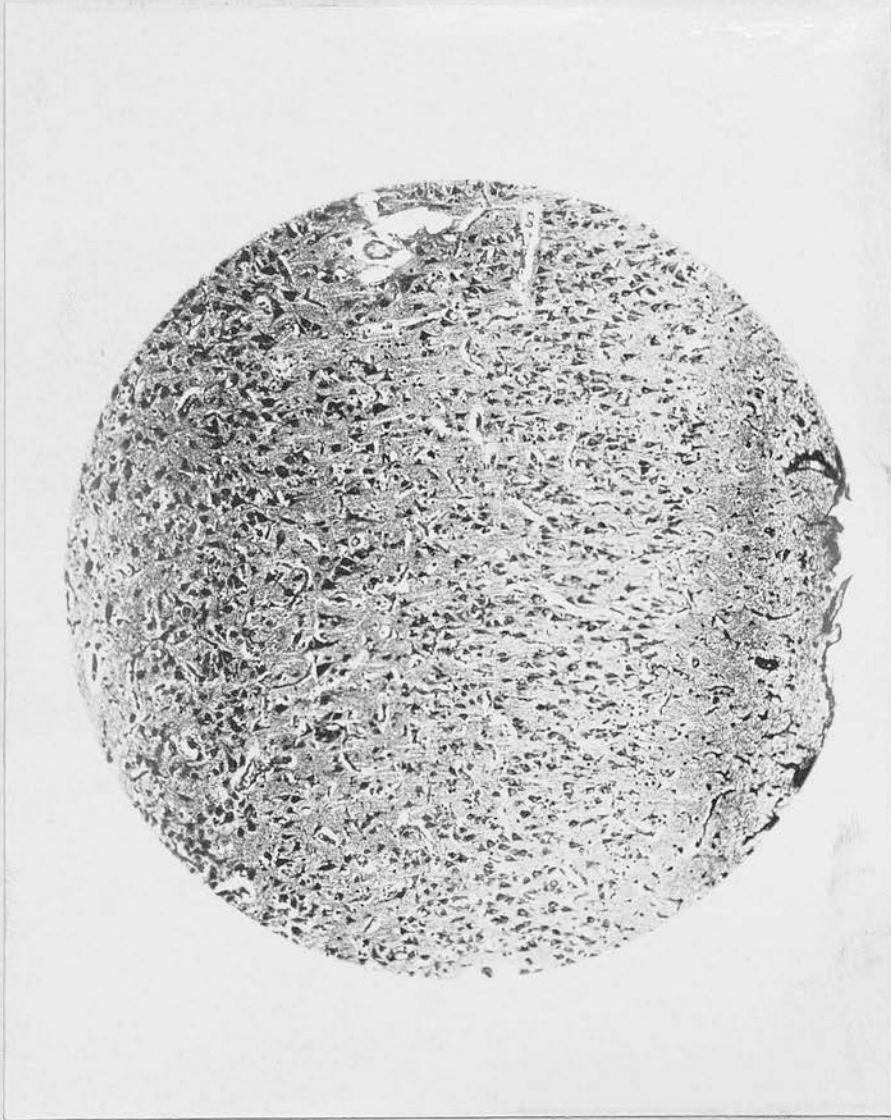
The Neopallid cortex is perhaps proportionately a little deeper and the cell lamination is better defined but remains the same as already described. There are certain differences in depth of the cortex in some areas and an increase or reduction of one or other of the layers especially the deepest but the arrangement throughout the Neopallium is so fundamentally similar that a detailed account of these slight variations is unnecessary.

The Rhinic area in most of its extent maintains the special features previously described and therefore possesses a more primitive structure though it contains numerous large cells.

The Ependymal Epithelium and the cells around it coincident with the greater specialization of the cortex, become greatly reduced, especially that lining

the /

SHEEP, near full time.
Marginal gyrus.
Cajal.



NOTE.

1. Definite Lamination of Cortex.
2. Cells mostly erect except in the deepest layer
3. Large deep pyramids well seen.

the inner wall of the ventricle.

Adult Sheep

A full description will be given and is taken from a specimen about one year old in which complete development has been attained. The main fissures present are the Calcarine-Intercalary, Lateral, posterior part of the Suprasylvian and the Rhinic and in addition to these there are some shallower furrows.

The Early Sections not far from the extremity of the occipital lobe do not call for any special description and the cortical structure appears to be essentially the same on both surfaces of the brain, and will be detailed later.

More anterior sections show that certain changes occur which become better marked the further forward the sections pass.

The Mesial Surface of the lobe soon becomes divided into two distinct areas;

1. Upper which extends from about the level of the future corpus callosum to the superior border which soon comes into close opposition with its fellow of the opposite side and which has developed in it the Calcarine-Intercalary fissure. This area retains the original cortical structure.
2. Lower which soon becomes hollowed to receive the mid-brain and which extends from about the level of the Corpus Callosum to the lower border of the hemisphere. The brain wall in this situation undergoes a gradual thinning owing to the pressure exerted by the mid-brain and /

and the cortex, at first of the same depth as that in other parts gradually becomes thinned and the individual layers fuse, the small cells disappearing entirely and the large cells remaining. At the same time they are pushed nearer the ventricle and finally come to lie just outside it where they form a very prominent narrow band of extremely well-developed large pyramidal cells which are set almost entirely vertically and send their apical processes outwards in the deep and clear overlying molecular layer, thus confessing a radial striatum in this region. Beneath this prominent layer a few scattered large cells lie nearer to the ventricle. Below, this layer becomes continuous with the cortex of the Rhinic area

Above it curves on itself near the upper pole of the ventricle and passes outwards to become continuous with the cortex above in the future site of the Corpus Callosum and here there is cortex of an intermediate type, passing upwards towards the Intercalary fissure. It is in this region that the Corpus Callosum gradually appears.

Later on another change occurs in this lower area for there appears between the brain wall and the surface of the mid-brain a small rounded mass of dark angular cells. This soon becomes elongated and the cells become arranged in a circular fashion at its periphery thus enclosing a clear reticular centre, ^{whole} the structure being surrounded by its own molecular layer. It appears to be a superadded structure developed between the

brain /

brain wall and the mid-brain and its inner surface soon fuses with the brain wall and becomes absorbed into it. Finally the inner layer of cells fuses with that prominent layer placed near the ventricle and soon after this it becomes interrupted and ends above and below in a recurved expansion, between which there lies a clear and structureless area which is thinned and finally becomes invaginated into the ventricle in the formation of the choroid plexus.

The above structures belong to the cornu ammonis.

The Neopallid Cortex which extends from the level of the corpus callosum to the Rhinic fissure appears to possess an essentially similar structure in its whole extent, though there are slight differences in certain parts.

The general type of cell lamination is as follows :-

1. Molecular layer of considerable depth. There are ~~some~~ large cells scattered through it but most of the cells are very small.
2. Layer of small pyramidal cells.
3. Layer of medium pyramids. In these two layers the cells are mostly placed vertically and together they form a broad band of well developed angular cells.
4. Layer of small irregular and angular cells which are supported by a plentiful reticulum. This layer varies a little in depth and is deepest on the outer surface of the brain but in general forms a well marked band interposed between layers of large cells.
5. Layer of large pyramidal cells almost all of which are set vertically. This layer forms the most striking feature /

feature of the Neopallid cortex for even under a low power the cells stand out prominently and they appear to ~~respond~~ specially well to the silver method for in many cases they stain extremely well whilst cells of other layers remain unstained. The cells forming this layer are large pyramids with very long apical processes which pass outwards and end amongst the outer layers of small and medium pyramids and they confer a radial striation on the overlying cortex. Several processes pass off from their bases but are short and fail to respond to the stain very well.

In general these large cells are not very abundant, but in the lower lip of the Intercalary fissure they become more numerous but at the same time do not stand out so prominently as elsewhere and in the gyrus fornicatus are much more stumpy and pale.

This layer does not lie at a constant depth for the layers above and below it vary in breadth in certain areas and thus it comes to lie either more superficially or more deeply relatively.

6. Layer of small irregular cells which are fusiform, rounded or multipolar and lie next the medullary centre extending into its superficial parts. Among the smaller cells there are occasional larger pyramidal or multipolar cells. This layer varies greatly in depth and is greatly reduced at the bottom of all the sulci where many of the cells become circumferentially arranged and are markedly fusiform as though they have been flattened by the infolding of the cortex to form

the /

the fissure. Between this layer and the overlying large cells there is a narrow clear reticular layer quite distinct on the outer surface but practically absent on the mesial aspect of the hemisphere.

Generally, the cortex is a little deeper in the lateral surface owing to a greater development of the small celled layers which lie on either side of the large pyramids, and on the mesial surface from the level of the Intercalary fissure to the level of the Corpus Callosum the cortex gradually becomes thinned and the individual layers fuse to a great extent while the superficial pyramidal layers are suppressed. The Gyrus Fornicatus therefore displays a more primitive structure.

The Rhinic Area shows a distinctive structure. As the Rhinic fissure is approached the cortical structure begins to change and the large pyramids seen in the Neopallidic cortex above become less prominent. That ~~cort~~ cortex which lines the upper lip of the Rhinic fissure conforms more or less closely to the description given above and its depth is considerable, whilst in the lower lip the cortex is much narrower and soon begins to change in type and the lamination is lost. The special features are as follows :-

1. The Molecular layer is very deep and very clear owing to small size of the contained cells and their comparative fewness, but at the lower border of the area, the molecular layer is very narrow.

2. The cells are arranged to form a prominent

peripheral /

peripheral layer with a very irregular outline and the cells tend to be arranged in clusters. Large cells predominate and the smaller peripheral cells seen above are much reduced, being replaced by larger pyramidal or stellate cells set irregularly. This layer passes round the lower border of the hemisphere to become continuous with the layer of large cells on the inner aspect but at the lower border it changes in type for the large cells are replaced by small irregular cells which lie nearer the surface.

3. Beneath this peripheral layer there is a loosely arranged layer of irregular medium sized pale cells and in the white centre between this and the ventricle there are numerous scattered cells which however cannot be arranged into definite layers.

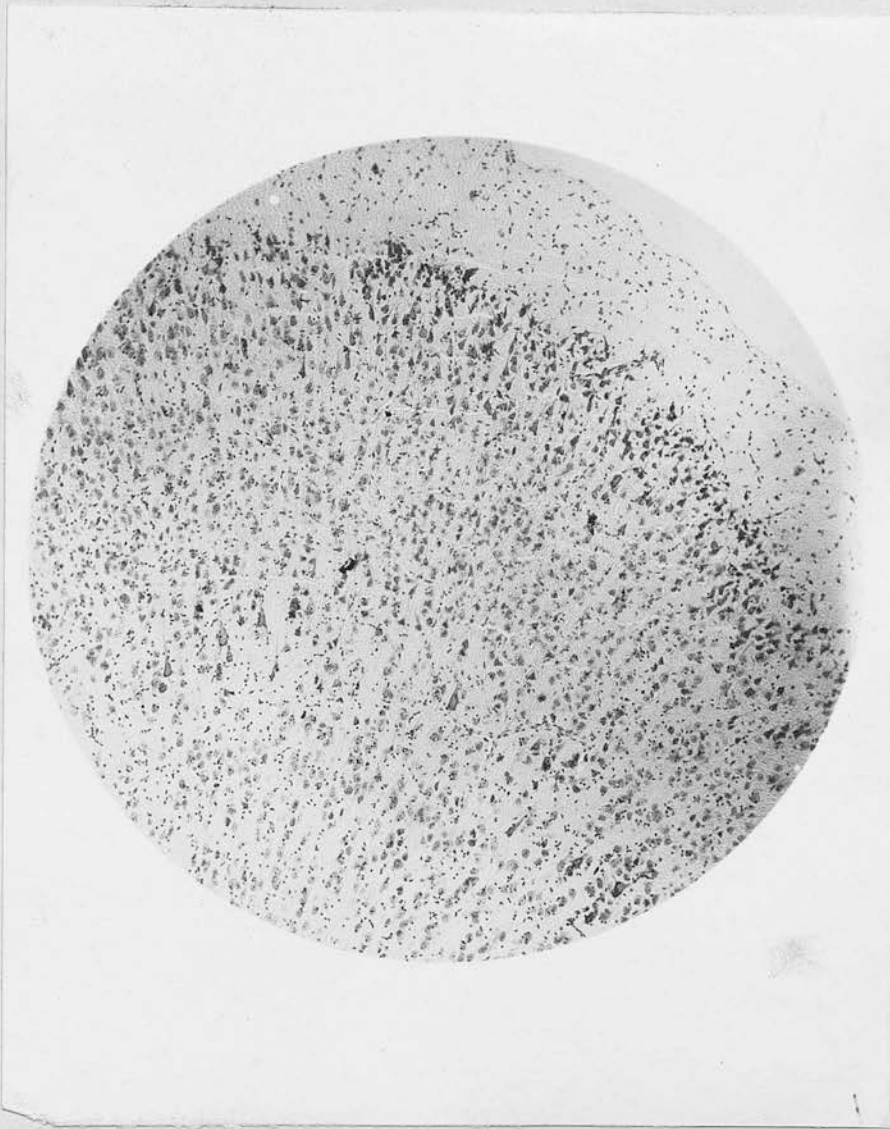
In the more anterior sections therefore the cortex of the Rhinic area presents three distinct areas, viz. an upper junctional part which passes into the Rhinic fissure and there conforms to the general type; an intermediate, with the special characters noted above; and a lower junctional part lying at the lower border of the area and passing into the mesial surface.

The Ependymal Epithelium consists of a layer of columnar or cubical cells set close together.

SHEEP Adult.

Nissl.

Marginal gyrus.

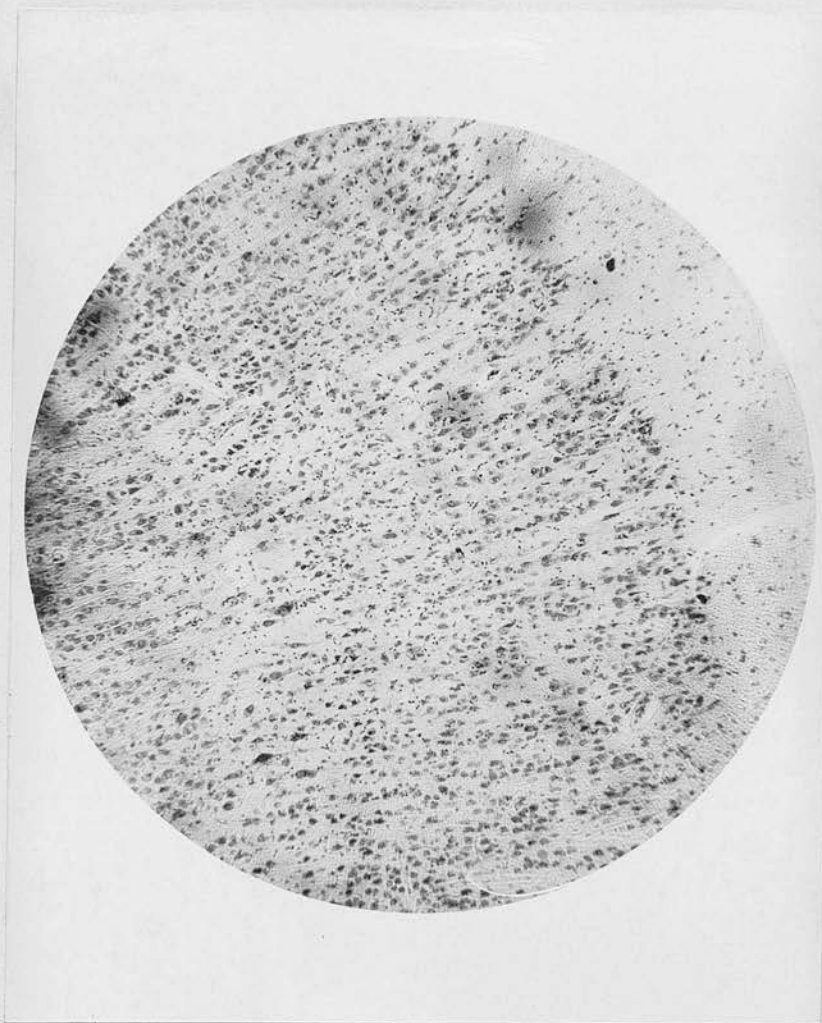


NOTE.

1. Lamination of Cortex very distinct and six layers easily definable.
2. Superficial pyramidal layers fairly deep.
3. Deep pyramids scanty.

Adult SHEEP,

Cortex between Lateral and Rhinic Sulci.

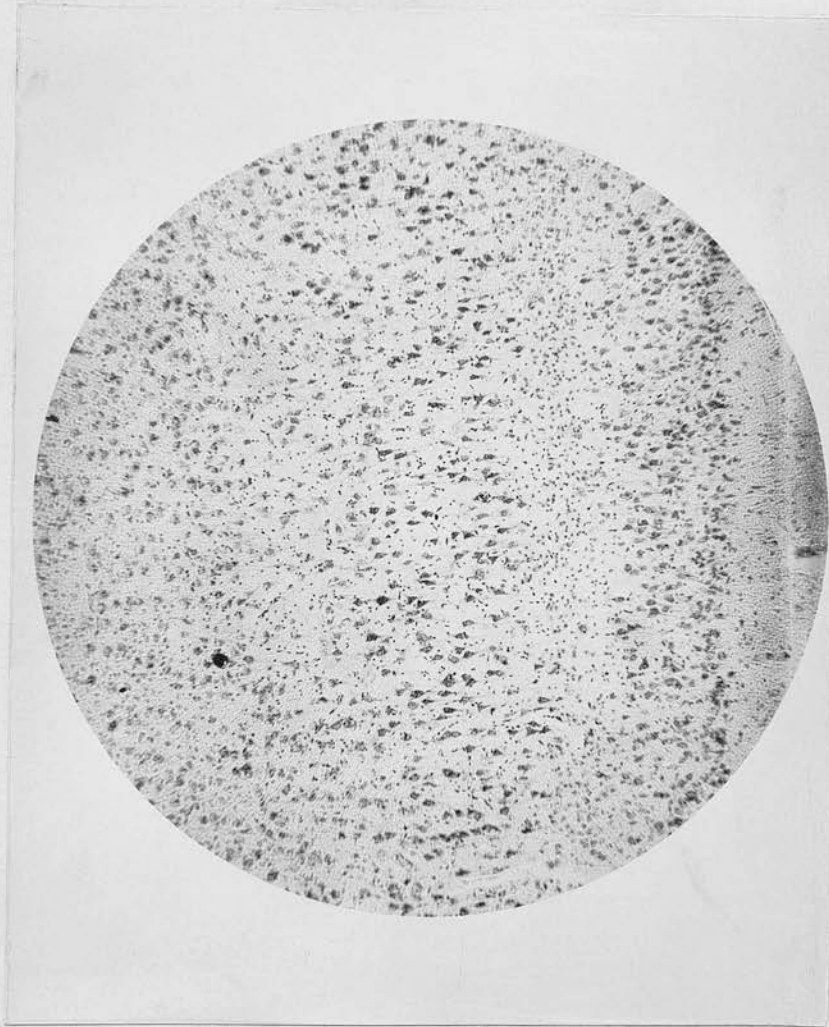


NOTE.

1. Superficial pyramidal layers slightly reduced.
2. Intermediate small cell layer relatively deeper.
3. Large deep pyramids very scanty.

Adult SHEEP.

Gyrus Fornicatus.

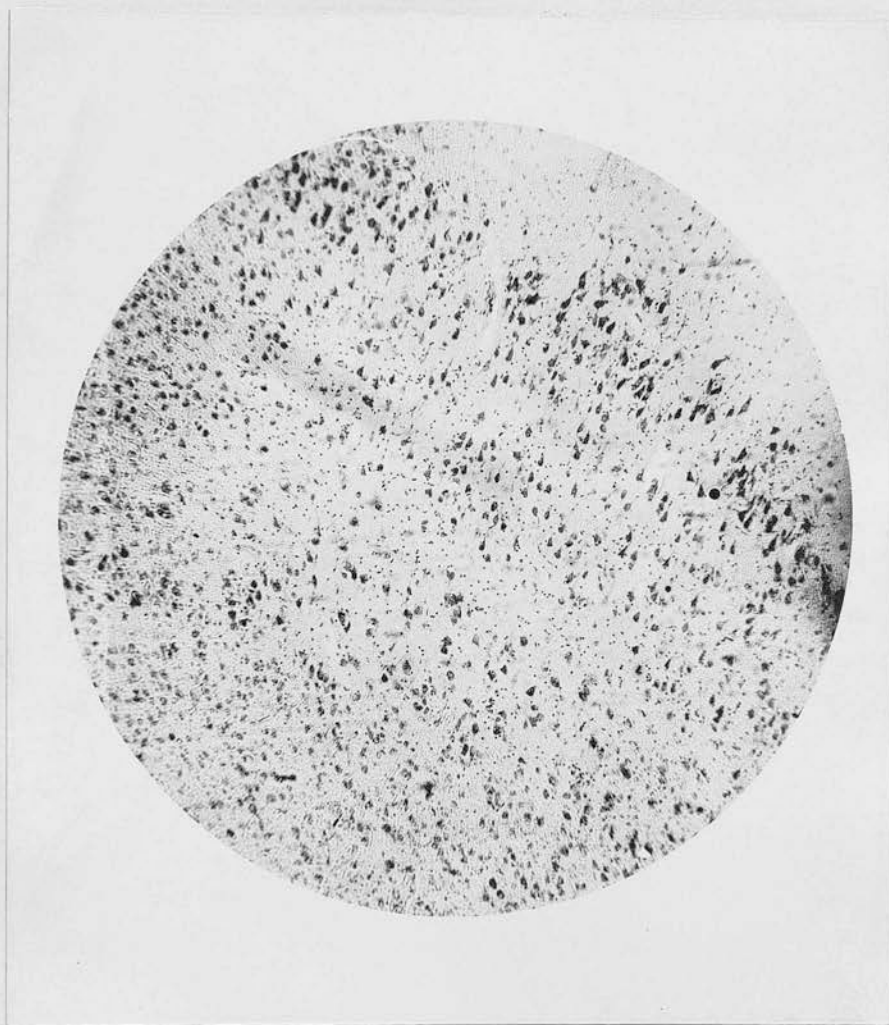


NOTE.

1. Layers clearly defined.
2. Relative reduction of superficial layers.
3. Relative increase of large deep cells.

Adult SHEEP.

Rhinc Area.



NOTE.

1. The clusters of superficial polymorphs.
2. Primitive type of cortex generally.

Summary.

On reviewing the changes observed in the development of the occipital region of the sheep's brain it will be seen that in the 1.5 cm. Embryo, the youngest examined we begin with an extremely primitive stage of the neural tube which consists of the following layers :-

1. Peripheral Reticular layer.
2. Mantle or intermediate cellular layer.
3. Ependymal or internal Epithelium layer.

These will be dealt with in turn and the changes which occur in them summarized.

The Peripheral Reticular layer soon comes to form the most external layer of the cerebral cortex and is then called variously, the Molecular, Plexiform or Zonal layer by different authors. It appears first as a narrow coarsely reticular layer with no evident cells, though the outermost cells of the next layer extend irregularly into its deeper part. Its development advanced this layer becomes broader and cells gradually appear irregularly in it until in a 10 cm fetus the cells are disposed in two distinct layers:-

1. Outer placed near the surface formed of scanty large elongated faintly staining cells with branching processes often placed parallel to the surface.
2. Inner composed of much more numerous smaller cells with round darkly stained nuclei.

These cells are supported by a plentiful coarse reticulum and in the older specimens the neuroglial network becomes much denser. The only changes that occur later are an increase in the number of the cells, and the

depth /

depth of the layer.

The Mantle or Cellular layer is at first composed of large actively growing young nerve cells, some being still of the round germinal type, whilst many are pyriform neuroblasts, and all show active mitosis. This layer in great part goes to form the important Cellular portion of the cortex and undergoes a progressive subdivision into layers up to a certain stage, whilst at the same time the cells advance from their primitive state and gradually become angular, stellate or pyramidal, developing processes and varying greatly in size.

In a 4 cm Embryo the Mantle layer has become divided into a narrow peripheral layer which is the earliest stage of the cellular cortex and which progressively increases in depth and complexity, and a broader inner layer of cells which surround the ependymal layer, and which in the later specimens becomes progressively reduced in amount. Between these two cellular layers lies an intermediate reticular zone which is the early white or medullary centre. The Mantle layer is thus early subdivided and from now on most attention will be paid to the important cortical layer, for the inner layer undergoes a steady reduction especially upon the mesial surface until in a 20 cm foetus it has practically disappeared though a narrow layer of grey matter still persists on the lateral aspect and poles of the ventricle.

In a 10 cm foetus a great advance has occurred and the cellular cortex beneath the molecular layer has become

divided /

divided into three layers in great part. At the same time the hemisphere can be divided into several parts for the distinction between the Rhinic and Neopallidic area is well marked, the former being of a more primitive type. The Neopallidic cortex above consists of two areas, a lower in which the subdivision into layers is very distinct, and an upper which passes round the superior border of the hemisphere and includes the upper part of the mesial surface, in which the cortical structure is much denser though the same layers can be made out. On the mesial surface the cortex is easily divisible into an upper thick part and a lower part which becomes more and more tapered off, finally undergoing the changes noted later.

From 10 to 16 cms., growth evidently goes on very rapidly and the three main fissures of this region make their appearance and complicate the sections.

These are the posterior ends of the Intercalary, *Calcar.*, Lateral and Rhinic Sulci and the latter is the first to appear.

The cells, too develop very rapidly at this stage and assume a definite angular shape as in the adult. The cortex becomes relatively deeper and increases in complexity.

In a 16 cm foetus the Neopallidic cortex has become 4 or 5 layered and the cells of the various layers vary in type and some large pale multipolar cells make their appearance among the intermediate layers.

The Rhinic area assumes a still more distinctive structure and is now separated from the rest of the

cortex /

cortex by the deep Rhinic fissure. The whole brain wall is thinner and the cortex is narrower, has a very wavy outline, and the outer cells tend to form clusters, and it contains many large pale cells.

The Mesial aspect of the hemisphere shows certain characteristic changes as the sections pass forwards. It becomes divided by the Corpus callosum into an upper part which forms the true mesial surface and which bears the intercalary fissure and a lower part which undergoes gradual reduction, the cortex being reduced to form a very prominent band of large pyramidal cells. This part lies in apposition with the mid brain and there appears gradually in the interval between them a rounded mass of cells which later joins the narrow cortical layer and finally becomes interrupted by the formation of the choroidal fissure. The large size of the pyramidal cells which persist as a narrow layer in this area is very striking. The whole structure forms the cornu ammonis and its primitive structure indicates its relations to an older portion of the brain, viz. Rhinencephalon.

In a 20 cm foetus the lamination of the cortex has become still more complicated and has practically reached the adult type. It is five or six layered according as the peripheral cells are sub-divided into two sets or not, and the most striking feature has been the development of a deep layer of large multi-polar cells mostly of pyramidal type which have numerous processes and abundant Nissl granules.

Growth has evidently advanced very rapidly and four

main fissures are now present for the posterior branch of the suprasylvian has joined the others.

The cells generally have developed considerably and are now of the adult type, many being pyramidal and being set vertically .

The Ependymal Layer which surrounds the ventricular cavity is very prominent in the youngest embryo and consists of tall columnar cells placed upon a very definite internal limiting membrane, and extending outwards to form a supporting network or Myelosponge for the mantle layer . These cells gradually become reduced in length and in a 20 cm foetus appear as short columnar or cuboidal cells lining the ventricle, with an extremely small amount of grey matter around them. It will thus be evident that the Ependymal layer and inner part of the mantle layer surrounding it undergo a steady reduction, coincident with the steady advance in growth and importance of the cortex.

So far I have reviewed the changes as far as the 20 cm foetus and it is evident that at this stage a high degree of development has been reached. The cell lamination of the cortex has attained the adult condition and throughout the Neopallium can be regarded as six layered. Changes subsequent to this principally centre round a growth in size of the cells, an increase in their angularity, and a greater development of their processes though the cells at this stage are well developed and possess numerous Nissl granules

Evidently /

Evidently growth is most active between 10 and 20 cms for below 10 the brain structure is still of a very indeterminate character and the rapidity of growth afterwards is very striking.

Evidently also the full development of the cortex and its subdivision into the six-layered type proceed pari passu with the development of the main sulci of this region, as these appear between 12 and 20 cms when growth is most rapid and in the 20 cm foetus in which the cortex has become fully subdivided all the four main sulci of the occipital region have become well marked.

Proceeding now to the adult sheep there are several points of interest. The Neopallid cortex is six layered in its whole extent and the cell lamination appears to be essentially the same throughout. There are however, certain minor differences and the area of cortex which lies between the Lateral and Rhinic fissures is perhaps not quite so definite as that above, for the pyramidal cells of the fifth layer are relatively not so large and at the same time the sixth layer is somewhat increased. The gyrus fornicatus has been shown to possess a special structure.

This raises the question of the localization of the Visual cortex and from what has already been said regarding the development and homologies of the Intercalary-Calcarine fissure or splenial complex it might be expected that the Visual area would be related to it. Further, it was noted in the course of

development /

development that the cortex in this region and around the superior border of the hemisphere is denser, has more numerous cells and also that the early differentiation of the cortex into its various layers is specially well seen in this area. It has also been noted that the large pyramids of the fifth layer are very numerous at an early stage.

The cortex which extends from the lower lip of the Calcar. Intercalary fissure becomes much reduced and its layers tend to fuse, but passing upwards we find cortex of exactly the same type as that around the fissure and this extends throughout the marginal gyrus, round the superior border and down on the lateral surface as far as the Lateral sulcus, below which as noted there are minor differences.

If the Visual area is denoted by cortex of this type it must extend over a wide area and it is difficult to place a lower limit to it on the lateral surface of the hemisphere but it is probably indicated by the lateral fissure.

Returning to the structure of the cortex, the superficial layers call for no special comment except to note that the majority of the cells are placed vertically. The deep layer of large pyramids forms a striking feature of the cortex and from a consideration of their size, wealth of processes granularity and early development one would regard them important cortical units. They appear first in a 16 cm foetus and at 20 cms have increased to form a very broad layer, which is relatively more extensive than in the adult. Furthermore these

cells /

cells come into close relation with the cells of all the other layers of the cortex for Cajal preparations show that the very long apical process passes right into the surface layers giving off on its way numerous horizontal collaterals which ramify amongst the intermediate cell layers. The basal dendrites are mostly horizontal or oblique and ramify amongst the deeper layers. The axis cylinder process fails to stain in almost all cases, whilst the long and thick apical processes bulk largely in the formation of the Radiary Plexus.

Lastly the Neopallid Cortex is capable of subdivision into areas whose limits are indicated by the main fissures. Thus the fornicat^e and marginal gyri possess a distinctive cell structure, and that portion of cortex which lies between the Lateral and Rhinic fissures is different from both.

The Marginal gyrus displays the most definite cortical structure of all.

Development of the Choroid Plexus.

In the Embryo of 1.5 cms, the youngest examined, there is no Choroid Plexus formed.

In an Embryo of 2.5 cms it has been noted that the mesial brain wall becomes gradually thinned as the sections pass forwards into the hemisphere. Finally at a point opposite the upper end of the Foramen of Monro, the brain wall is reduced to the Ependymal layer and this thinned portion becomes invaginated into the cavity of the lateral ventricle by a large thin-walled blood vessel which descends from above in the interval between the hemisphere and the mid brain. The invaginated portion forms a finger like process which at this stage is only slightly convoluted and presents a wavy outline. This structure, the earliest stage in the development of the Choroid Plexus, consists of the supporting vessel whose wall is formed by a single layer of elongated and endothelial cells, and the invaginated epithelium which covers the vessel consists of tall columnar cells with nuclei set at different levels. Internally these cells lie upon a very definite limiting membrane, whilst their outer ends rest upon the supporting vessel.

In an Embryo of 4 cms the structure has become more complicated and the invaginated process has become much convoluted and now forms a definite plexus which is divisible into two distinct parts :- A proximal long stem which is more or less straight, in which the cellular covering is thicker for in addition to the

ependymal /

Foetal SHEEP. Plexus Cajal.

6 cms.



- NOTE. 1. Choroidal cells tall columnar.
2. Cell very clearly outlined by the silver.
3. Plexus much convoluted.

ependymal epithelium some of the round cells of the mantle layer are also invaginated into the ventricle especially on the lower aspect and intervene between the vessel and the superjacent ependyma; a distal convoluted part in which the vascular plexus is covered almost entirely by the ependymal layer which consists of tall columnar cells with large oval or rounded nuclei, placed close together.

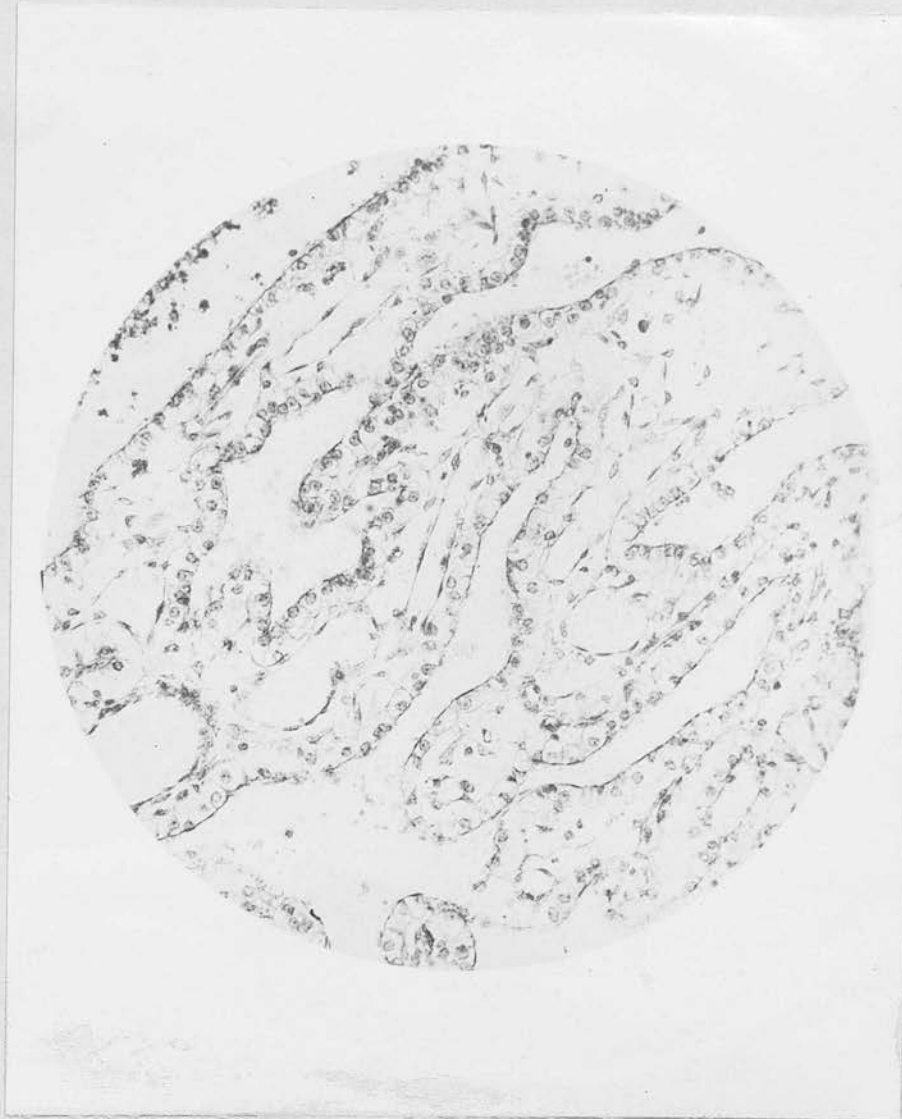
The blood vessel which gives off the choroidal branch now extends through the whole extent of the mesial brain wall and the invaginating vessel appears rather to come off the lower part. In the previous embryo it was noted that this vessel descended from above and that the main trunk did not extend along the whole surface of the hemisphere, which in its lower part is fused to the adjacent mid brain by a wide cellular bridge.

In foeti up to a length of 16 cms certain changes occur gradually in the structure of the plexus. It becomes very much more convoluted and is relatively much larger; the cells covering the proximal straight part become steadily reduced to form, in the 16 cm specimen, a single layer of cuboidal cells on the upper aspect and columnar on the lower, set closely together and staining darkly and coming continuous with the lining ependyma at the point where the brain wall is invaginated; the cells covering the distal convoluted part of the plexus are of a different type. At first tall and columnar they steadily become both relatively shorter and broader and have very definite outlines. In the main they are very clear, though at places their protoplasm

becomes /

SHEEP. Choroid Plexus. Nissl.

16 cms.



NOTE. 1. Choroidal Epithelium now cuboidal.
2. Plexus much convoluted.

becomes more granular. The nuclei stain darkly and are oval or rounded and are placed at a variable level though many lie near the periphery. The Choroidal Epithelium hence comes to resemble very closely the cells of the secreting glands and this similarity becomes all the better marked in the older specimens. In a foetus of 20 cms all these changes have become better marked and the cells have become still more cuboidal and from this stage onwards the choroidal epithelium undergoes a progressive reduction and in a 30 cm foetus has become almost entirely cuboidal though columnar cells occur in places. In the foeti approaching full time the cells become shortly cuboidal or flattened, thus resembling the adult condition and presenting a very marked contrast to the very large cells present in the early foetal series extending up to 20 cms.

Hence it will be seen that the choroidal epithelium undergoes certain changes in the course of full development and is most prominent in foeti ranging from about 5 to 20 cms subsequent to which it undergoes a very marked reduction and the large columnar cells finally become relatively very much reduced and are either flattened or shortly cuboidal. This reduction in size and type of the choroidal epithelium goes on approximately pari passu with the change in the ependymal epithelium as might be expected from their similar origin.

Series of Foetal Pigs.

A series ranging from an Embryo of 1.4cm's up to a foetus of 20 cm has been examined, but little need be said, with regard to it except to point out the principal differences which exist between it and a series of foetal sheep of the same range. In general, the developmental stages to be observed correspond very closely to those already described in the sheep, but if anything the Pig embryo's of the same length shew a higher degree of development than the sheep for the cells assume a more definitely angular shape and have more distinct bodies at an earlier age. Whether this is due to their having been better preserved is difficult to say but the conditions under which the two sets of embryos were obtained and preserved have been the same.

A strong impression is also given that the subdivision of the Cortex takes place sooner in the pig.

A third striking difference between the two series becomes apparent in the older members and consists in an earlier and better development of the fissures in the pig.

In a 10 cm foetus

A faint sulcus is present in the lateral surface of the hemisphere and this is evidently the hinder end of the Rhinic fissure for the brain structure below it is much more primitive than above. This difference between the upper and lower /

lower portions of Cortex in the lateral surface has been noted in a sheep of the same age but no fissure has appeared to mark the separation externally.

In a 15 cm foetus

the fissuring has advanced very greatly and the calcarine-Inter Calary, Lateral and Rhinic fissures are all well marked and the appearance at this stage is very similar to that seen in a 20 cm sheep.

In a 20 cm foetus

the development of the fissures has gone still further and the posterior end of the Suprasylvian sulcus has been added to the others. At this stage the Calcarine-Intercalary and Lateral fissures lie very near each other. The whole appearance corresponds fairly closely with that seen in a sheep of 27 or 30 cms.

In accordance with these changes the cortex will be seen to have advanced similarly and merits a brief description.

In Embryos up to 10 cms the structure is essentially the same but even at this early stage the cells have become more definitely angular in the pig.

In a 10 cm foetus

the Neopallid cortex is divisible into four layers the cells beneath the molecular layer being divided into an inner and outer set by an intermediate opener layer. Many of the cells are markedly angular or pyramidal tapering off to a point

and /

and being set vertically.

In a 15 cm foetus

the Neopallial cortex appears to be of practically the same structure in its whole extent and consists of the following layers :-

1. Molecular.
2. Broad and closely packed layer of small angular cells the intermost of which are largest, might be described as a separate layer.
3. Fairly thick layer of large vertical pyramidal cells sending their *apical* processes outwards, which form the most outstanding feature of the cortex at this stage.
4. Variable layer of small or medium sized irregular cells. This layer varies in depth and is much reduced at the bottom of the fissures.

In the area lying between the lateral and Rhinic fissures this layer is increased in depth and thus makes the whole cortex deeper.

In some places a few of the large cells of the third layer appear to wander out and form an indefinite layer amongst the outer band of small cells.

On the mesial surface of the brain the cortex becomes greatly attenuated below the region of the Calcarine-Intercalary fissure and is pushed outwards by the mid brain. It is reduced to two layers of cells and gradually becomes divided up in the manner already described in the sheep's brain.

The Rhinic Area

is separated from the Neopallium

by /

by a deep fissure and has a modified structure. The large cells predominate as in the sheep's brain.

In a 20 cm foetus

the development has advanced still further and the cortex has become six layered in the whole extent of the neopallium. The cell lamination is as follows :-

1. Molecular layer of ordinary type.
2. Layer of small or medium irregular and angular cells.
3. Layer of scanty larger pyramidal cells set vertically whose processes fail to stain properly.
4. Layer of small irregular cells similar to those at the surface, but more numerous and forming a broad zone.
5. Layer of large pyramids, almost all of which are placed vertically, sending a well marked apical process out towards the surface and having a few indefinite ill-stained basal processes. This layer forms the most striking feature of the cortex and though present throughout appears to be best defined in the region of the Intercalary fissure where the cells are most abundant.
6. Layer of irregular cells of variable size and shape lying next the white centre. This layer varies in depth and is much reduced at the bottom of Sulci. Beneath it lying in the superficial part of the white centre are some large scattered cells many of which are highly fusiform. Though present throughout the Neopallium they are /

are best seen towards the upper border of the hemisphere, and at the bottom of the Sulci lie parallel to the surface giving the impression that they have been flattened by the ingrowth of the cortex to form the fissure.

The above structure is present in the whole extent of the Neopallium with slight differences in thickness of the Cortical layers here and there, whilst mesially the same changes already described take place.

The Rhinic Area calls for a special description except to note the depth of the molecular layer, and the predominance of the large cells, which pass outwards and invade to a great extent the peripheral cellular layers.

Lastly one may call attention to the degree of development of the nerve cells generally and especially of the large pyramids and to the fact that almost all of these ^{are} erect and send their apical processes outwards.

This concludes the pig foetal series and though it may seem a short one it will be seen later from the description of the adult pig that the cell lamination of the Neopallial cortex has reached the adult condition, and subsequent changes up to full-time must consist almost entirely of a fuller development of the nerve cells and their processes which will render the subdivisions into layers yet more definite. It will further be noted that, with the completion of the fissuration, the cortex attains the adult /

adult type of lamination and has become in general six-layered. There are certain minor differences in the various layers in different areas, but the bulk of the Neopallial cortex conforms to the general type. Reference will be made to these differences in the adult pig.

Adult Pig.

Sections across the posterior end of the ventricle show that well marked differences exist between certain portions of the Neopallial cortex though it is possible to reduce practically the whole area to a general type of lamination. This will be mentioned first and then the variations in the different areas pointed out. The portion of brain under brain is deeply indented by the Calcarine intercalary, the lateral and the Rhinic fissures with some smaller subsidiary furrows between them.

General type of cell lamination of Neopallium

1. Molecular layer of considerable depth, containing scanty large pale cells superficially and small dark cells deeply.
2. Layer of small angular and pyramidal cells.
3. Layer of medium pyramidal cells.

These two layers may quite well be considered together and form a narrow band of variable depth.

4. Open layer of small irregular angular cells supported evidently by a plentiful fibre reticulum with a few larger cells in it.
5. Layer of large vertical pyramidal cells, few in number generally but the largest in the whole cortex. They are erect with apical dendrons passing outwards amongst the superficial layers, and a few short basal processes passing horizontally.
6. Broad layer of small irregular and fusiform cells.

This layer is extremely variable in depth being greatly reduced at the bottom of the Sulci and there having its cells arranged circumferentially.

Variations in different Areas :-

Area 1. This includes the gyrus fornicatus lying between the bottom of the Calcarine Intercalary and the corpus callosum, and is indented by the suprasplenic sulcus. In this area the total depth of the cortex is much reduced and a gradual attenuation goes on down to the level of the commissure. At the same time the individual layers become better defined through the texture being opener.

The surface pyramids are greatly reduced and become much smaller and irregular near the commissure, while the large pyramids of the 5th. layer are relatively increased. Prior to the formation of the corpus callosum this large pyramid layer was directly continuous in the mesial surface with the large cells of the Cornu Ammonis.

Area.2. Lying between the Calcarine intercalary and lateral fissures and including the Gyrus Marginalis.

In this area, especially at the convexity of the Gyrus, the cortex is of considerable depth. The superficial pyramidal layers are well marked, though the cells are not numerous nor of large size. They are mostly placed vertically with their apical dendrons passing outwards.

The reticular small cell layer is broad. The deep pyramids are scanty but very well defined.

The deepest layer is broad and contains in its deeper part many small elongated pyramids set vertically.

Area 3, Lying between the lateral and Rhinic fissures.

Here the lamination is not so definite as in area 2 though the total depth of the cortex is greater, owing to an increase in the breadth of the deepest layer.

Near the Rhinic fissure the cortex begins to show a transition to a simpler type.

The Rhinic Area

possesses a much more rudimentary structure and is made up of four laminae :-

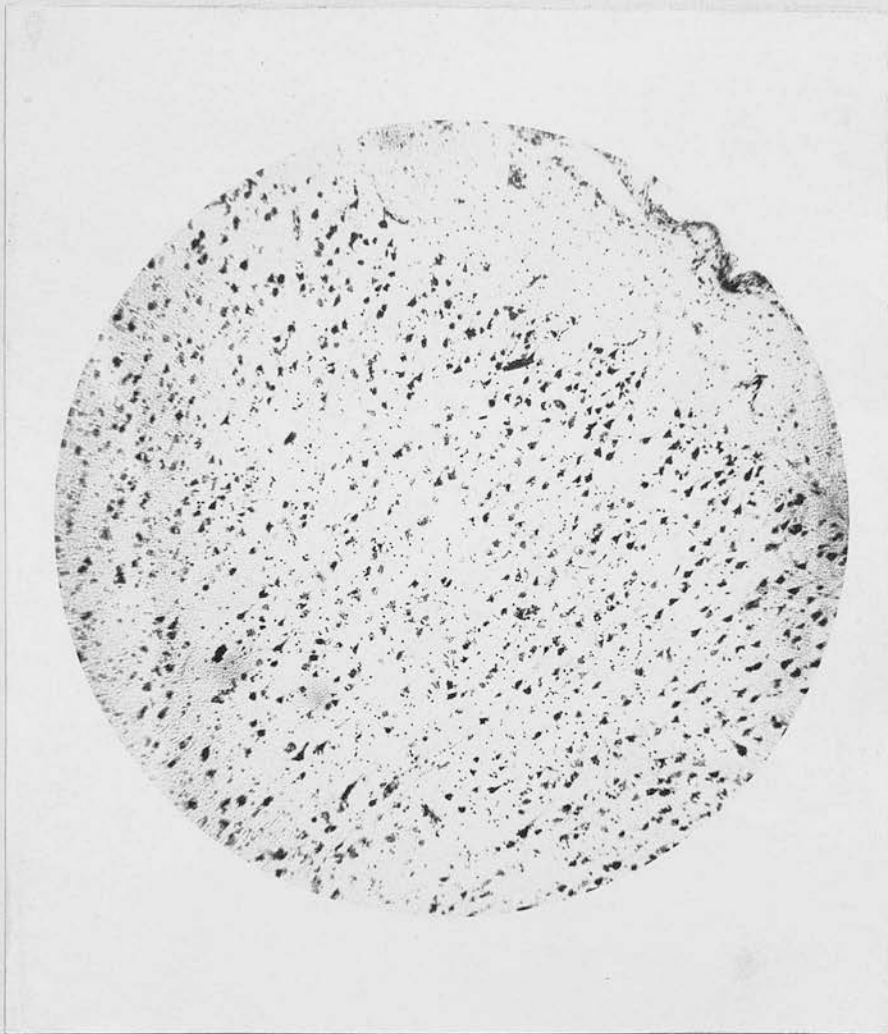
1. The Molecular is of great depth and contains very few cells.
2. Outer layer of large angular dark stained cells placed quite irregularly. These cells show the usual tendency to form clusters.
3. Broad open reticular layer.
4. Deep layer of medium sized fusiform and angular cells lying next the white matter.

The area is therefore characterized by the depth of the Molecular layer and the predominance of large darkly staining cells near the surface.

The Neopallial Cortex, therefore, as in the sheep can be subdivided into area by the main sulci and of these the Marginal gyrus displays the most distinctive structure.

Adult. FIG.

Marginal gyrus.



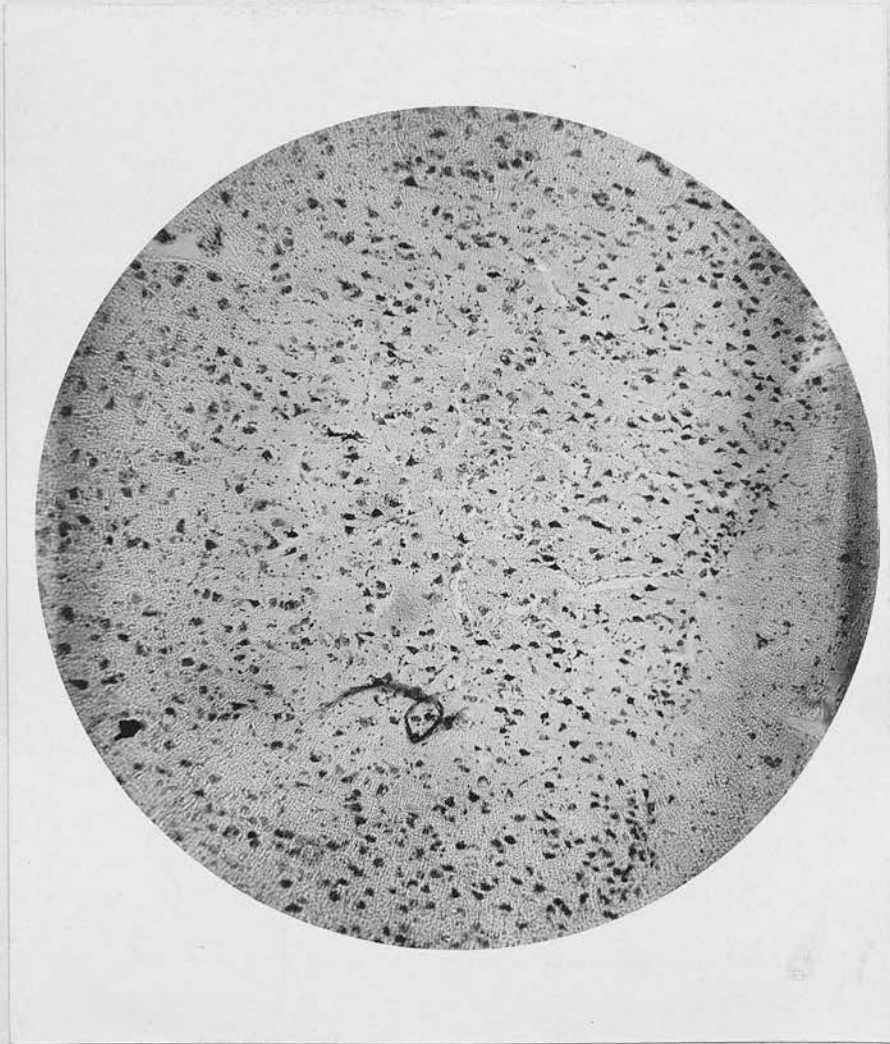
NOTE.

1. Lamination fairly definite.
2. Superficial pyramidal layer of no great depth
3. Small celled layer broad.
4. Deep large pyramids scanty.

Adult PIG,

Nissl.

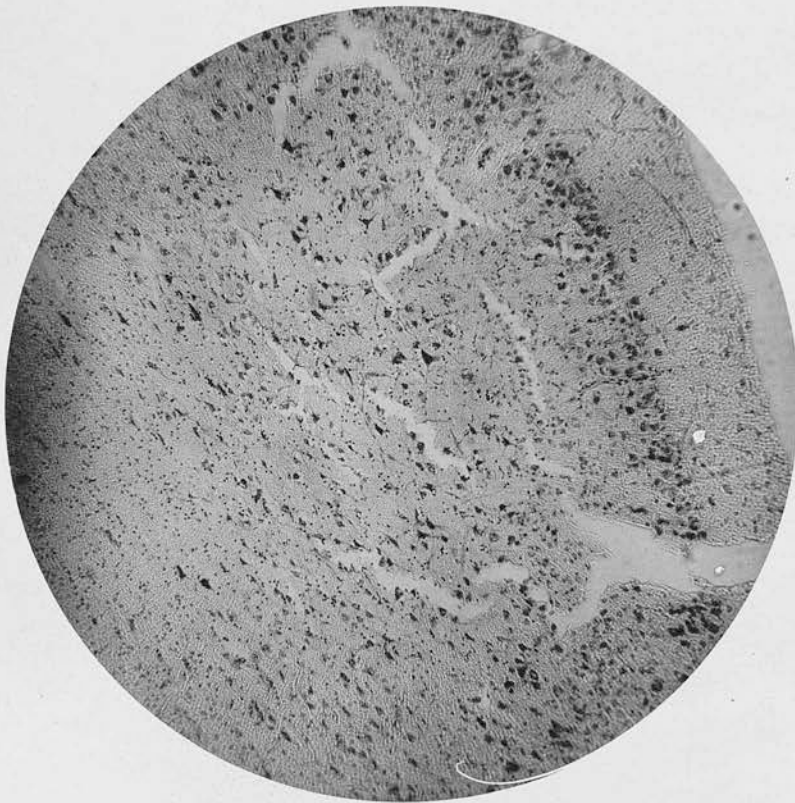
Cortex lying between Lateral and Rhinic Sulci.



NOTE.

1. Lamination much less defined.
2. Cells appear more of one type.

Adult Pig.
Cyrus fornicatus.

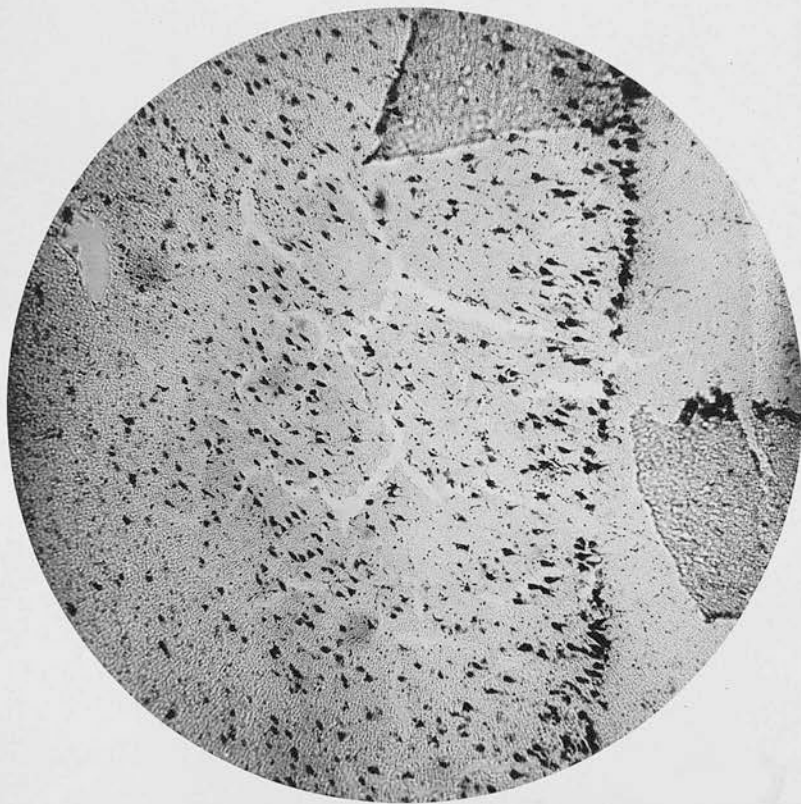


NOTE.

1. Reduction in depth of Cortex..
2. Superficial pyramidal layers specialll reduced.
3. Nested arrangement of superficial polymorph cells not so well marked as in other groups.

Adult PIC, '8

Rhinic Area.



NOTE.

1. Primitive type of cortex.
2. Superficial polymorphs relatively few
and clustered arrangement not so marked.
3. Two artifacts appear in section.

Series of Ferret Brains.

This commences with an Embryo of 6 mm and passes gradually at short intervals up to the newly born animal. As these brains have not been stained by any of the special methods it will not be possible to give a detailed account of the cell structure, and the description will be confined to a general account of the changes observed during the course of full development, the subdivision of the primary layers of the brain wall, &c. The description given will in most cases be taken from sections which pass across the posterior end of the ventricle.

In an Embryo of 6mm the brain wall is extremely thin and consists of a layer of cells, several deep, lying between very distinct internal and external limiting membranes. These cells are large rounded or oval neuroblasts, closely packed. All possess distinct nuclei, and many contain several small black points which almost certainly indicate the mitotic processes going on in the cells and judging by the number of cells which contain these dark granules, the process must be going on very rapidly at this stage.

Adjacent connective tissue cells and especially the large nucleated red blood corpuscles show the mitotic processes extremely well.

Both walls of the brain are at first of about equal thickness, but more anterior sections show that the mesial wall comes to be about twice as deep as the

lateral /

FERRET, 6mm. X 85.

Vertical section through developing head.



NOTE.

1. Primitive structure of brain wall
2. The thick mesial brain wall.
3. Thinning at upper pole.
4. Close resemblance between hemisphere and mid-brain.

lateral, which seems to lag behind in growth. Both walls are tapered towards the superior border of the hemisphere and around this border and for some distance downwards on the lateral surface the brain wall consists simply of a single layer of cells lying between the limiting membranes.

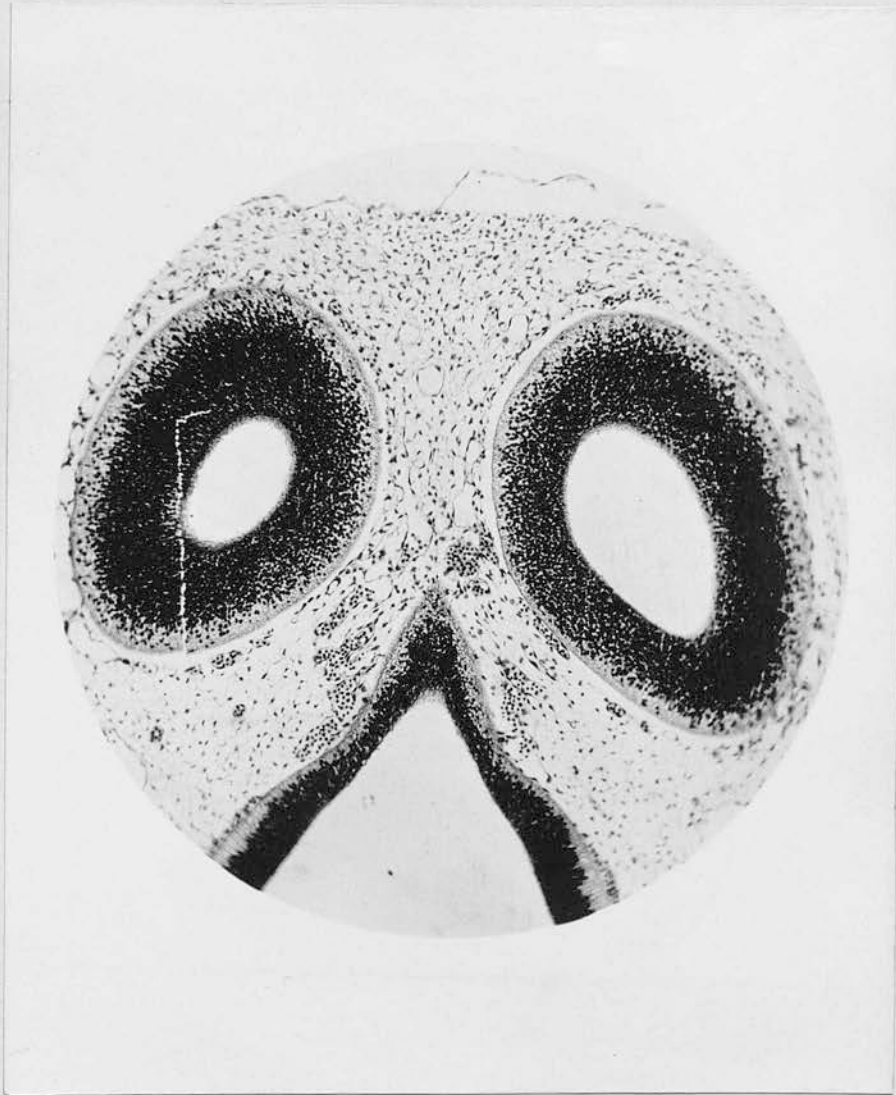
It is interesting to note that the tube of the midbrain shows a similar structure, being tapered off above into a thin lamina of flattened cells.

The brain wall therefore at this stage displays its earliest and most rudimentary structure, consisting simply of an aggregation of actively growing and dividing neuroblasts, enclosed by two limiting membranes

In an Embryo of 8.2 mm. the structure shows a considerable advance and the brain wall is now divided into three layers: -

1. Peripheral reticular layer, broader on the lateral surface, and containing scattered large round cells, very scanty near the surface, more numerous deeper down
2. A broad mantle layer composed of large rounded or pyriform cells, closely packed. This cellular layer is very much deeper than in the previous embryo, the cells are larger, many are more distinctly pyriform, and the mitotic processes are evidently very active.
3. Internal Ependymal layer of columnar cells which pass outwards into the mantle layer and rest internally in a limiting membrane. These cells are not very clearly marked off from one another and their inner portions are clear and apparently homogeneous, thus forming a clear area around the ventricle. Some of

FERRET 8.2 mm. X85.



NOTE.

1. Peripheral reticular layer.
2. Very deep Mantle layer - the outermost layer.
3. Ependymal layer.

the rounded germinal cells show mitotic figures specially well.

The inner wall of the hemisphere at this stage is thinner than the outer and the molecular or peripheral reticular layer is reduced and the more anterior sections show that these differences become better marked.

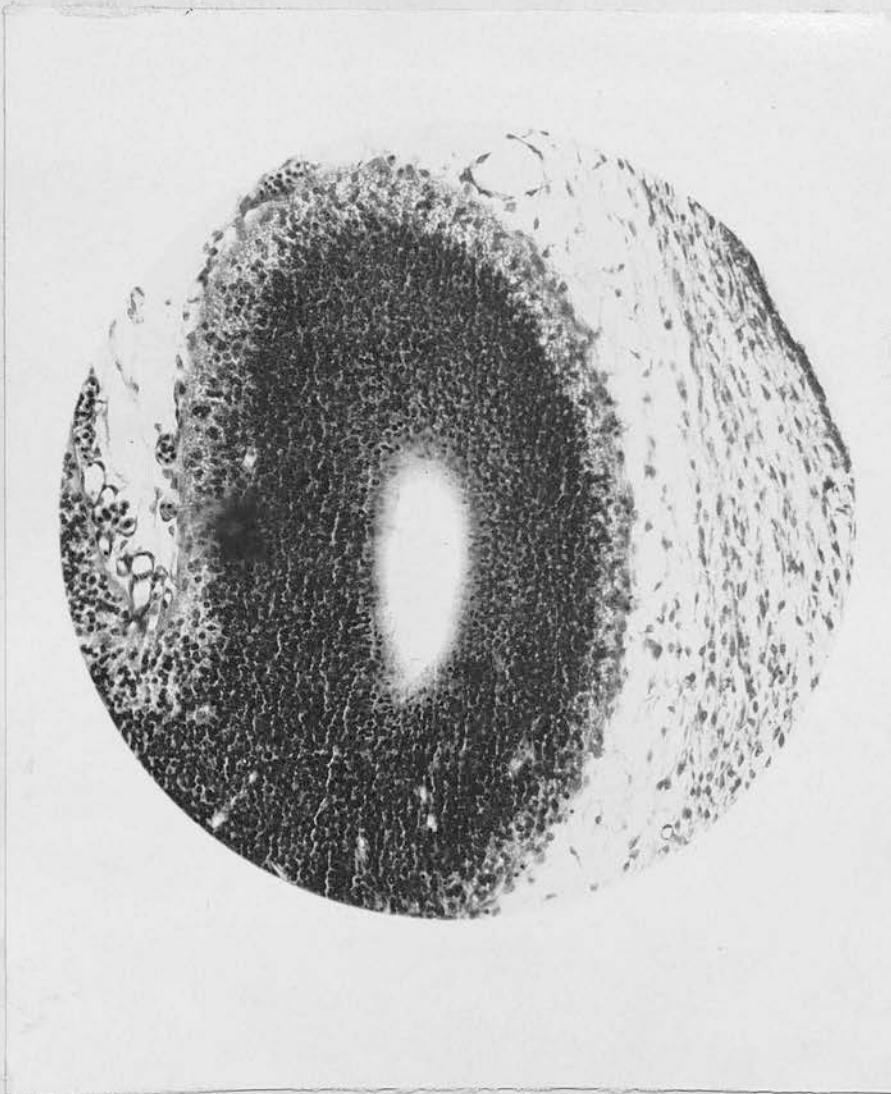
At this early stage the outermost cells of the mantle layer are not so closely packed and are specially oval or pyriform and thus may be regarded as forming a special layer.

The Embryo of 10 mm calls for no special description, except to note that the structures previously described become better defined, the outer cells of the mantle layer forming a more distinct band and a narrow opener layer appearing between the Ependymal epithelium and the thick cellular layer.

An Embryo of 13.5 mm shows that the structure of the brain wall is as follows : -

1. Peripheral reticular layer (henceforth called the molecular) of fair width containing numerous cells in its deepest part.
2. Narrow loose layer of large cells, much better marked on the lateral surface. The cells are almost all pyriform and as the sections pass forwards they become more numerous and come to form a prominent peripheral layer on the outer surface whilst mesially there is practically no advance.

FERRET, 10 m.m.



NOTE.

1. Peripheral reticular layer.
2. Broad Mantle layer.
3. Numerous dark germ cells showing mitosis
in the Ependymal layer.

FERRET, 13.5 cms.

X 47.



NOTE.

1. Differentiation of brain wall more advanced laterally.
2. Peripheral Cortical cell layer split off from the Mantle layer in the lateral wall.

3. Open reticular layer containing smaller scattered cells, very narrow at first, but gradually coming to form a broad layer externally.
4. Layer of oval or fusiform cells which are set parallel to the surface. This layer is very scanty in the early sections, and remains so mesially, but laterally soon forms a broad and very distinct layer, which is specially prominent owing to its cells being placed at right angles to the cells of the other layers.
5. Broad layer of closely packed large oval or pyriform cells - the deeper part of the original mantle layer.
6. Ependymal Epithelium the cells still being of considerable length.

Mitotic processes are still very active.

An Embryo of 17 mm. shows very little change. The subdivision of the lateral brain wall is the same though the layers are more distinct. The mesial wall is only about half the depth of the lateral, thus showing that there must be distinct variations in growth activity in the two walls, for in the earliest embryo examined the mesial wall was much the thicker. The lower part of the hemisphere is broader than the upper, a point also noted in the youngest embryo.

A foetus of 23.5 mm. shows that differentiation has advanced considerably, even the sections through the extremity of the occipital lobe showing that there is a

prominent /

prominent peripheral cell layer lying next the Molecular, much better marked in the lateral surface.

The Lateral brain wall shows the following layers which are quite distinct even in the earliest sections across the ventricle :-

1. Molecular layer of moderate depth, containing numerous cells, many of which are elongated and placed parallel to the surface.
2. Prominent layer of large pyriform neuroblasts several deep, packed closely together.
3. Clear reticular layer of about the same depth as the preceeding, built up of a very distinct reticulum of fibres scattered between which are a fair number of cells of various types.
4. Layer of smaller pyriform cells set mostly vertically lying directly upon the next layer.
5. Layer of elongated fusiform cells, smaller than the cells of the outer layers, a great many being set obliquely or even parallel to the surface especially towards the upper and lower borders of the hemisphere.

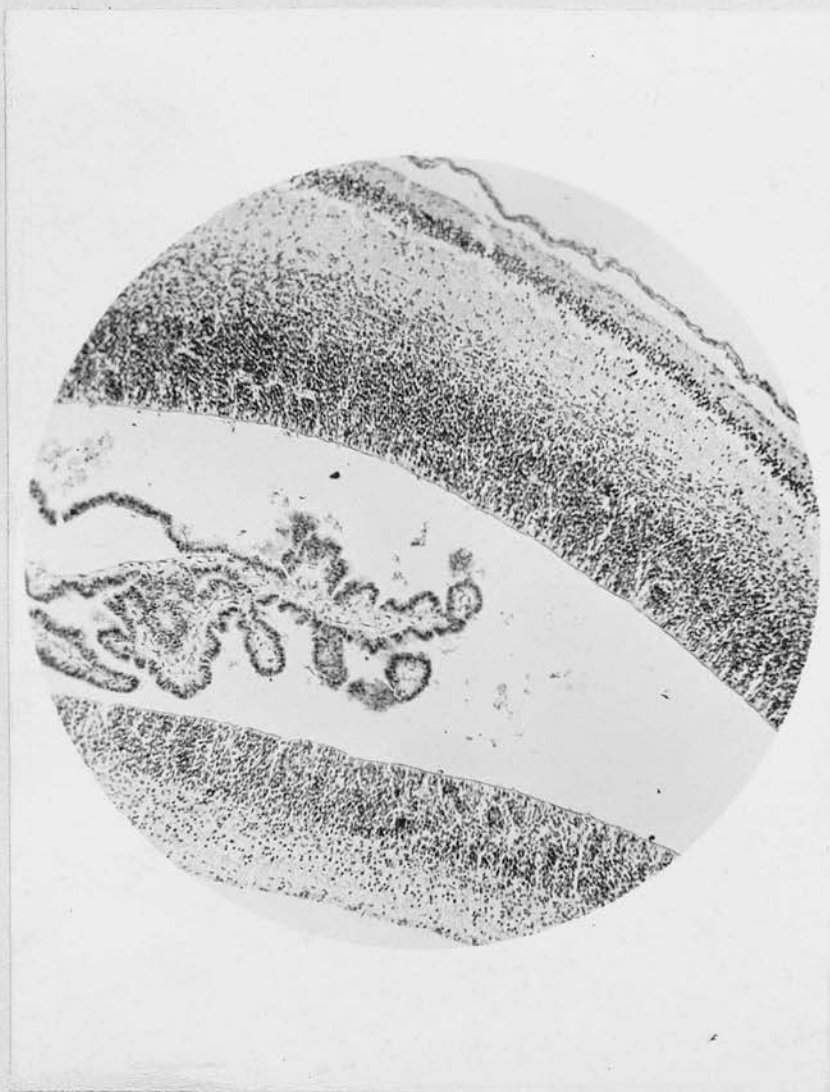
The two preceding layers have evidently arisen out of the single layer of spindle cells described in earlier embryos by a re-arrangement of the outermost cells, which are more rounded or pyriform.

6. Broad layer of closely packed large pyriform neuroblasts, not so deep relatively as in earlier brains..
7. Ependymal layer in which the cells have become shorter, though still very prominent.

The Mesial brain wall is only about half as thick as
the /

FERRET, 17 mm.

X 93.

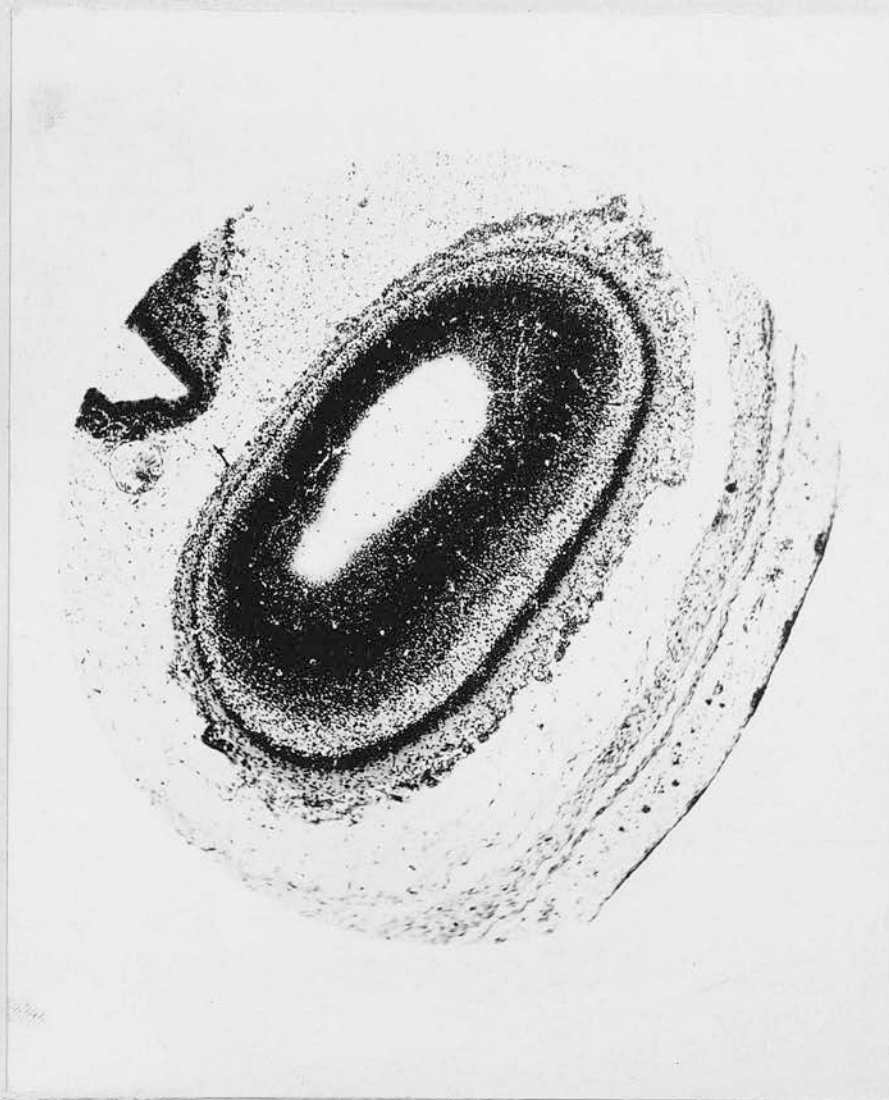


NOTE.

1. Early condition of the Choroid Plexus.
2. Differentiation of brain wall well started.
3. Peripheral Cortical cell layer well marked
in lateral wall.
4. Ependymal and germ cells well seen.

FERRET, 23.5 m. m.

X 47.



NOTE.

1. Further differentiation of brain wall.
2. Peripheral cortical layer very well marked laterally.
3. Further splitting up of Mantle layer.
4. The difference in depth of the lateral and mesial walls.

the outer and shows the following layers :-

1. Molecular.
2. Layer of scanty large round or pear shaped cells, one or two deep, thus very much thinner than the corresponding layer in the outer brain wall, but becoming thicker where the two layers become continuous above and below.
3. Narrow reticular layer, containing scattered large cells.
4. Narrow layer of spindle cells lying mostly parallel to surface.
5. Broad layer of large neuroblasts. } as already
6. Ependymal layer. } described.

The mesial wall hence shows a more primitive structure than the outer, is less well differentiated and the layers are all relatively much thinner.

Mitosis is still very active, the figures being particularly well seen in the Ependymal cells.

In a foetus of 25.5 mm, the structure remains essentially the same, but the cells and the layers show greater differentiation and the peripheral layer of large cells is much better marked. The general differences between the two brain walls are maintained.

In a foetus of 33 mm. consiserable advances have occurred.

The Lateral wall in sections across the hinder end of the ventricle shows the following structure :-

1. Molecular layer of average depth in which the cells are /

FERRET, X 90.

25.5 mm.



NOTE.

1. Differentiation much further advanced.
2. Relative depth and differentiation of the mesial and lateral wall.
3. Very prominent Cortical cell layer laterally.
4. Remainder of Mantle layer subdivided and Medullary centre well marked.

are more abundant than earlier brains.

2. Prominent band of closely packed darkly stained angular or pyramidal cells of large size set mostly vertically. In about the lower third of the wall this layer gradually becomes reduced until at the lower border it ceases to exist as a definite layer.

Beneath this layer there are a number of scattered large cells which might be regarded as a separate band.

3. Broad reticular layer containing numerous small fusiform or angular cells, with occasional larger ones.

4. A broad layer of small fusiform, oval or rounded cells, the deeper of which are set more irregularly than the outer, and at the upper limit of the ventricle become oblique and parallel to the surface, thus evidently being the remains of that layer seen in the early stages.

5. Fairly broad band of large neuroblasts which are assuming an angular or pyramidal shape. This layer has become relatively much reduced.

6. Ependymal Epithelium, the cells of which have also undergone reduction, though still tall and columnar with tapered outer ends which pass out amongst the cells of the previous layer.

The Mesial brain-wall presents the following points of difference :-

1. The Molecular layer at first of average thickness in its whole extent becomes thickened in its central and lower parts, and they are increased so as to form three layers, and external consisting of single scanty fusiform cells set parallel to the surface, a middle layer /

layer of similar and larger cells many of them set in the same way, and an internal, in which the cells are smaller, more irregular and darker.

2. The prominent outer layer of large angular cells which at first extends through the whole length of this surface is much thinner than on the outer wall, is tapered off at its lower end and this thin portion gradually disappears as a distinct layer and its lower end comes to lie at an increasingly higher level. The whole layer similarly becomes much thinner.

3. The open reticular layer is much thinner.

4. The two layers beneath are more distinct though not so broad for the deeper cells are more definitely placed parallel to the surface so that the two layers are set almost at right angles.

5. The deep cell layer and the Ependyma present no special features.

The deep layer of large cells in the more anterior sections becomes thickened near the lower end of the ventricle and on the inner side of this lying between it and the surface there appears a dark mass of cells which soon enlarges and presents a cavity in its centre. Its inner wall then fuses with thickened lower end of the layer described above and this portion then thins and breaks down thus dividing the cell mass into two parts. Similarly the inner layer of cells breaks down and the ventricular wall comes to consist simply of the Ependymal cells and this thin wall soon becomes invaginated into the ventricle by a large thin walled blood vessel which ascends in the internal between the mid brain and the hemisphere, and thus the Choroid

plexus is formed.

The lower portion of the hemisphere requires a special description as it differs from the other parts. Even in the early sections it is more massive than the upper part, and the more anterior sections show that a faint dip occurs on the surface just about the junction of the lower and upper two thirds of the hemisphere, which is probably the Early Rhinic fissure for it is at this point that the structure begins to be modified. The special features are :-

1. The peripheral layer of large cells becomes much reduced, and the cells are scantier though of very large size, pyriform or angular.
2. The clear area beneath is at first quite distinct but at the convexity of the lower border it becomes obliterated as the cells increase and thus there comes to be a broad mass of cells extending from the Molecular layer to the Ependymal layer, though the outermost are the larger and still form a definite layer.
3. The Molecular layer contains very few cells.

The cells, generally, are much further developed than in the earlier embryos and have assumed a more angular shape, though processes are still not very well defined. The largest and best developed cells are found in the prominent peripheral layer, and in the remains of the mantle layer around the ventricle. The cells of the intermediate layers are much smaller, are mostly markedly fusiform and possess small dark oval or rounded nuclei. While most are set vertically, some lie

parallel /

parallel to the surface.

Mitosis is evidently going on very actively for the figures are much in evidence.

In a foetus of 39 to 40 mm, though the same general features detailed for the last embryo are present there are distinct advances and points of difference.

The lateral wall consists of :-

1. The Molecular layer contains an outer and inner set of cells.
2. The layer of large cells is much broader and the cells are further advanced. It is tapered off below and with the appearance of the faint sulcus described changes its character in the lower part of the hemisphere. On its deep surface the loose layer of large* cells has become more extensive and may well be regarded as forming a separate zone.
3. The Reticular layer is broader and is for the most part formed of bundles of fibres running parallel to the surface. Scattered through it are numerous small cells, most of which are fusiform or pyramidal and are set vertically sending their apical processes outwards at right angles to the main fibres of the layer.
4. A broad layer of small irregular cells, mostly fusiform, loosely packed and supported by an abundant reticulum.
5. A broad layer of closely packed small irregular and deeply stained cells, set quite irregularly, a fair number being parallel to the surface.
6. A layer of larger closely packed cells, which is

much /

FERRET, 40 mm.

X 39.



NOTE.

1. Brain wall well differentiated.
2. Prominent corticall layer, best marked laterally
3. Remains of Mantle layer around Ventricle
still plentiful.

much narrower than in earlier embryos and is the deepest portion of the original mantle layer which has been undergoing gradual reduction.

7. Ependymal Epithelium, the cells being much shorter and approaching more to the adult condition.

The subdivision of this wall has therefore become more complete, and the different layers are more clearly demarcated.

The Mesial wall is thinner than the outer and shows the same general changes as in the previous brain, viz, a gradual thinning in its lower part and finally the interruption to admit the Choroid plexus. The layers of this wall are :-

1. Molecular, with two sets of cells.
2. Layer of closely packed vertically set large pyramidal cells thinner than that on the outer surface and gradually interrupted below.
3. Reticular layer containing numerous large angular cells and a very few small fusiform or pyramidal cells such as predominate in this layer in the outer wall. This layer is set directly upon the next are without the interventions of the loose layer of fusiform vertical cells so well seen in the lateral wall, for that appears to absent.
4. Broad layer of fairly large irregular cells, the deeper being fusiform and set mostly parallel to the surface.
5. Layer of large cells, closely packed and similar to that in the outer wall, but relatively much narrower.
6. Ependymal Epithelium which seems to have undergone

a greater reduction.

The Lower third or Rhinic Area of the hemisphere presents the same features noted in the previous embryo, but they are better marked and this part is very different from the upper portions of the brain. Between it and the ventricle there has gradually appeared a thick rounded mass of cells evidently developed from the lower ends of the cell layers around the ventricle.

Mitotic processes though still well seen in the Ependymal cells has become much less active and in association with this it is interesting to note that the majority of the red-blood corpuscles have lost their nuclei at this stage.

In a foetus of 42.5 mm. certain further advances have occurred :-

1. The peripheral cortical layer lying next the Molecular has become deeper, and the cells have developed further, on both surfaces of the hemisphere. The large scattered cells seen on its deep surface have become more abundant and more closely packed thus forming a more definite layer, especially laterally.
2. The broad reticular layer previously described has increased in width and the cells in it are much scantier and are of small size. This layer now evidently forms the white centre whilst the overlying layers constitute the true cortex. At this stage and with a non-differential stain it is difficult to divide the cortex into layers, but one can say that the largest cells lie deeply.

3. The deeper cell layers surrounding the ventricle show coincidentally with the greater development of the peripheral layers to form a more definite cortex, a reduction in relative importance, though still of considerable depth.

4. The Rhinic Area or lower third of the hemisphere has become even more clearly demarcated from the upper parts.

Foeti of 53 and 54 mm. and a newly born ferret present very similar features.

The cortex has become fully differentiated into layers, which will be described in detail later in the adult brain. Near the posterior extremity of the lobe the structure is similar on both surfaces of the hemisphere, but towards the lower border it is much tapered off. Laterally the limit between the Neopallial and Rhinic cortex is very clearly shown even in the early sections. Mesially the same changes detailed in previous brains occur, resulting in a gradual thinning of the brain wall, and its final invagination by the Choroid plexus. The Rhinic Area presents a special structure to be detailed later.

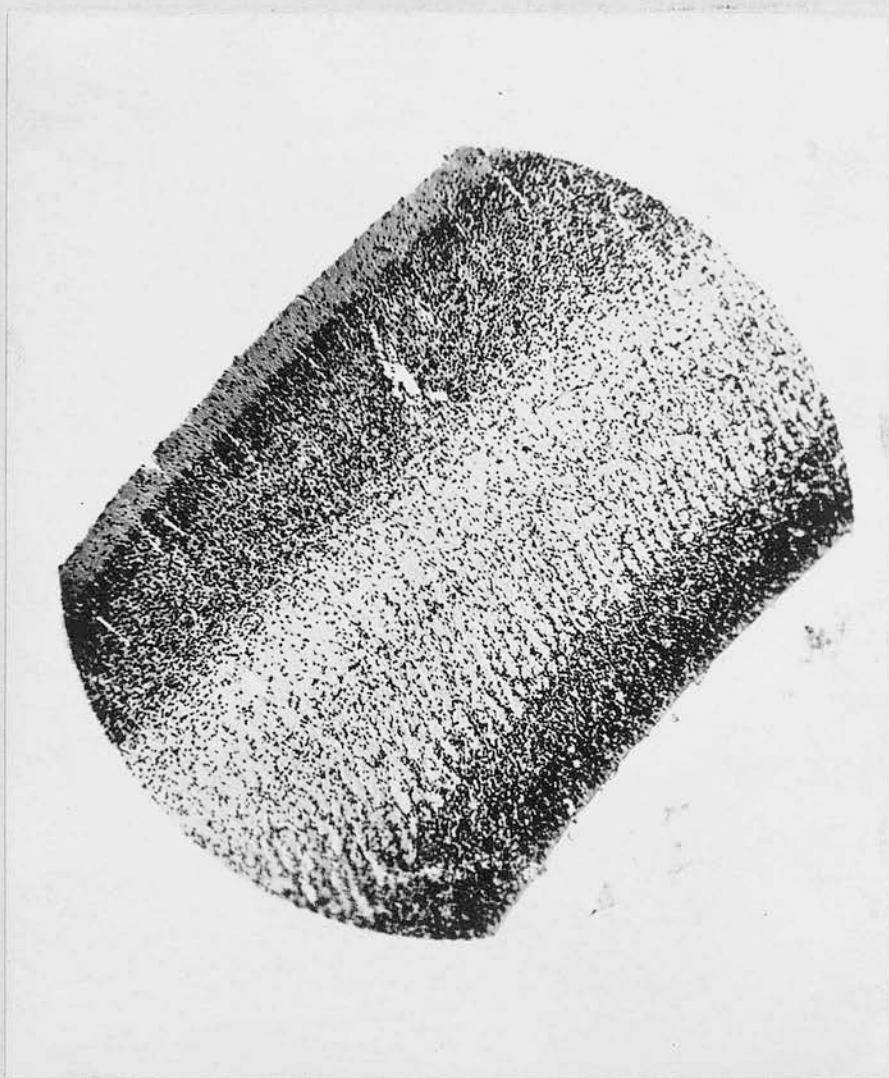
The Medullary centre is of fair depth and contains many small cells.

The Cellular layers around the ventricle have become greatly reduced, especially mesially in the more anterior sections. Laterally they are still abundant

and /

FERRET, full time,

X 93.



NOTE.

1. Complete differentiation of brain wall.
2. Various layers of cortex ill defined.
3. Cellular layers around ventricle still well marked.

and opposite the lower pole of the ventricle increase to form a large oval cell mass, indicating the Basal ganglia.

The Ependymal Epithelium has become reduced to a layer of short columnar cells.

Adult Ferret.

For its size this brain is well fissured and the occipital region shows well marked Calcarine-Intercalary, Lateral and Rhinic fissures with some smaller minor furrows. In correspondence with this, the cortex is well developed, and the cell lamination very clearly defined.

The Neopallid Cortex shows variations in structure in different parts and is capable of subdivision into areas. In general it conforms to the six or seven layered type, according as whether the superficial pyramidal layers are subdivided. The mesial and lateral surfaces of the hemisphere in the earlier sections show a roughly similar character but mesially changes soon occur and as the Corpus Callosum is reached the cortical structure alters entirely. The essential changes consist in the disappearance of the superficial pyramidal cells, an increase in depth of the small granular cells and finally the large cells of the fifth layer predominate. A gradual thinning of the mesial brain wall occurs and it is ultimately interrupted by the invaginating Choroid Plexus.

The description of the cortical lamination is taken from sections across the hinder end of the ventricle and the Corpus Callosum.

The Neopallid Cortex extending from the level of the Corpus Callosum to the Rhinic fissure can be divided into three areas, viz :-

Area I. This extends from the supero-mesial border to the lateral fissure and has a very definite lamination :-

1. Molecular layer of ordinary type.
2. Layer of small pyramids of fair depth. The cells are mostly erect.
3. Layer of scantier medium erect pyramids.
4. Layer of small granular and fusiform cells. This layer is very clearly defined and separates very clearly the superficial from the deep pyramids.
5. Layer of large erect pyramidal cells, set vertically, with outwardly directed apical dendrons. These cells are scanty but are the largest of the cortex and the apex dendron passes right out to end amongst the surface layers.
6. Fairly broad layer of small irregular angular and granular cells, which undergo reduction at the bottom of the sulci.

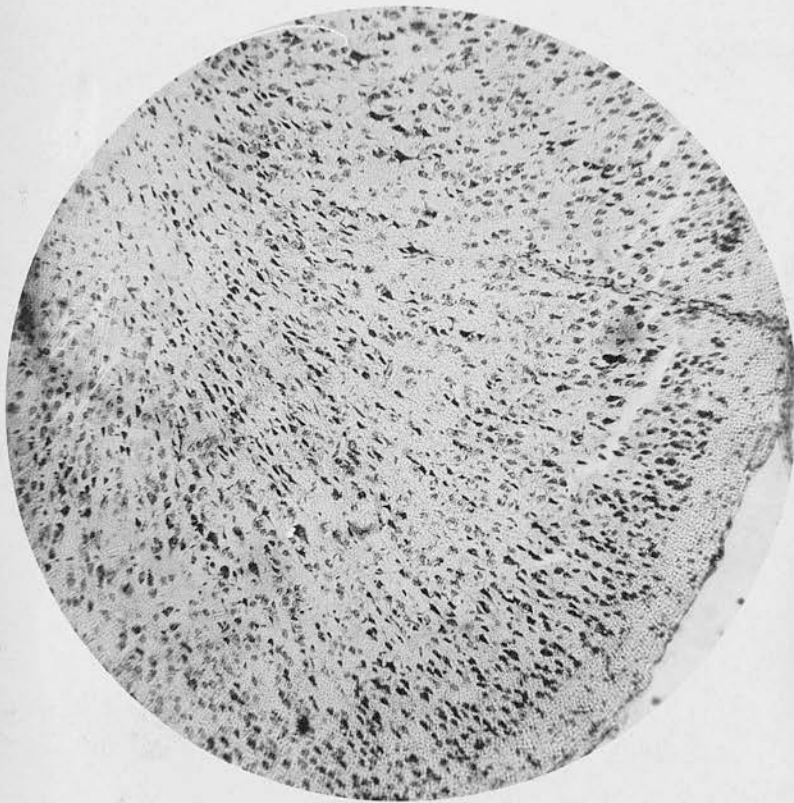
The above layers are extremely clearly defined and this may be taken as the type, from which certain variations occur on either side of the area.

Area II extends from the Calcarine Intercalary fissure to the Corpus Callosum. The depth of the cortex is gradually reduced as the Commissure is approached and the layers fuse to a great extent. The surface

pyramids /

Adult FERRET.

Marginal gyrus.

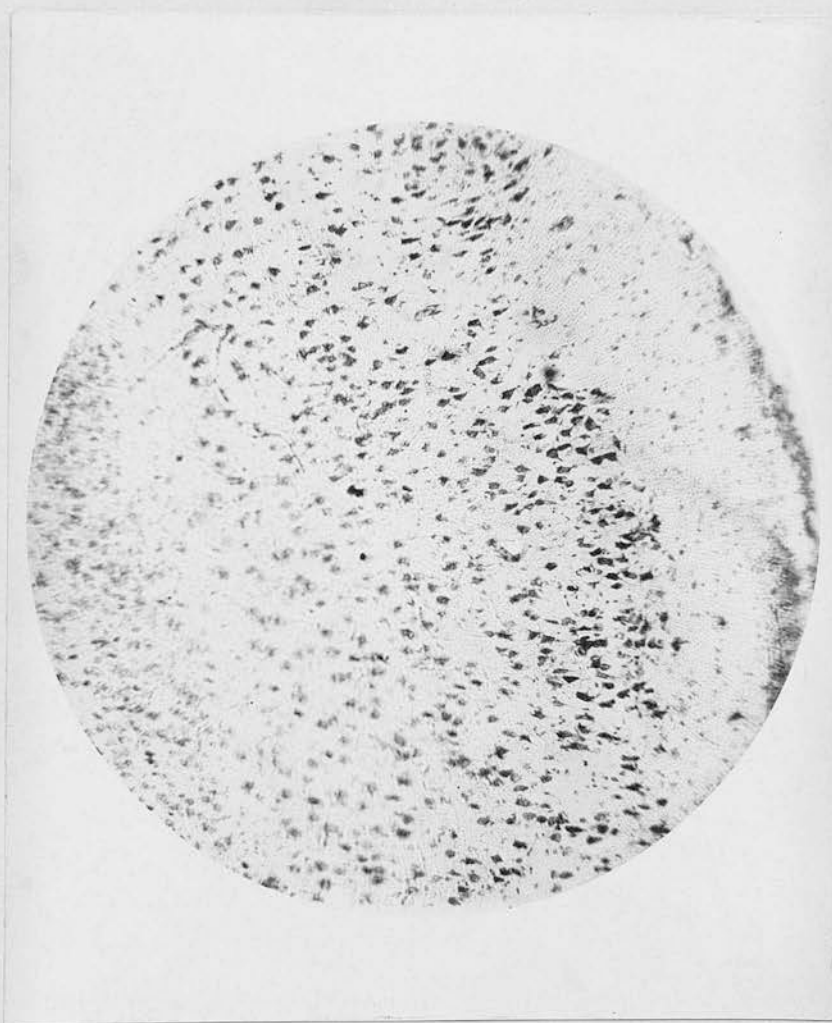


NOTE.

1. Lamination very distinct.
2. Superficial pyramids abundant.
3. Large deep pyramids prominent.

Adult FERRET.

Rhine Area.



NOTE.

1. Very deep Molecular layer.
2. Nested arrangement of superficial polymorphs.

pyramids are largely replaced by an increase and migration outwards of the small granular cells. The large deep pyramids are of a different type and are pale and stumpy.

Area III. This extends from the lateral down to the Rhinic fissure. The general depth of the cortex is increased considerably, this being due to a greater development of the small celled layers, viz, the fourth and the sixth.

At the same time the various layers are not so clearly differentiated and a certain amount of fusion occurs. The large deep pyramids are somewhat different, do not all lie erect and their processes do not stain so well. Near the Rhinic fissure shows a transition towards the olfactory type and the surface pyramids are greatly reduced.

The Rhinic Area displays the usual characters viz :-

1. Very deep Molecular layer.
2. Superficial layer of large irregular dark cells tending to become clustered.
3. Reticular layer containing fairly numerous small cells.
4. Deep and broad layer of medium sized irregular cells.

SUMMARY.

The development of the brain wall has been traced through all its stages till the adult type is attained. The rudiment of the cellular cortex is split off from
the /

the mantle layer about the time the foetus reaches 10mm. Thereafter it increases in depth and complexity, whilst the deeper part of the original mantle layer undergoes retrogressive changes and disappears in great part. The general changes are so similar to those already reviewed in other animals that no details need be added.

The Cortex, as might be expected from the degree of fissuration of the brain is well developed and conforms to the six or seven layered type. The cells are abundant, clearly defined and have numerous processes. Many are pyramidal and the superficial pyramidal layers are fairly deep.

The Visual Area. It has been pointed out that the Neopallid cortex can be subdivided into areas with certain variations in structure. The gyrus marginalis has a specially definite structure and from this and from its relation to the Calcarine-Intercalary fissure, one would ascribe the Visual function to it.

The Choroidal Epithelium. This undergoes certain changes in the course of development which are worth detailing. In the youngest 6mm embryo the mesial brain wall, as noted is thicker than the outer, there is no choroidal fissure and therefore no Choroid plexus. In an Embryo of 13.5 mm, the wide communication between the IIIrd. and lateral ventricles present in the younger embryos of 8 and 10 mm. has become narrowed to form the foramen of Monro, which at this stage is relatively a long canal. The mesial brain wall as noted, undergoes a gradual thinning and at a level corresponding to the opening of the foramen of Monro into the lateral
ventricle /

ventricle, it becomes reduced to a layer of columnar cells, which is invaginated into the ventricle by a large thin walled blood vessel which divides to form a mass of convoluted capillaries, which with their covering of invaginated Epithelium constitute the Choroid plexus. The Choroidal Epithelium hence consists essentially of a layer of columnar cells set closely together and containing large oval or rounded nuclei showing mitotic figures. On the lower surface of the invaginated blood vessel the Epithelial covering consists of a single layer of columnar cells but above some of the round neuroblasts which lie next the Ependymal cells are also invaginated and pass inwards for some distance upon the vessel. The Choroidal Epithelium hence arises from an invagination of the Ependymal cells which line the ventricle and is directly continuous with them.

An Embryo of 23.5 mm shows very similar features and the Epithelium is still columnar and that which covers the deepest convolutions of the plexus has the nuclei near the free border of the cells, whilst in the proximal part they are centrally placed. The basal portions of the cells are very clear and show little structure.

In an Embryo of 33 mm, the cells have become relatively shorter and the differences noted above between the distal and proximal parts is well marked.

In an Embryo of 40 mm, the cells are still shorter and at the convexity of the convolutions of the plexus are cuboidal rather than columnar and in a slightly older embryo cuboidal cells predominate, and cover practically the whole of the plexus.

Lastly /

Lastly, in the full-time ferret the choroidal cells are flattened or cuboidal especially on the early straight part of the plexus, a marked change from the tall columnar cells seen in the young embryos. This gradual reduction of the Choroidal Epithelial cells appears to proceed pari-passu with the reduction in length of the Ependymal cells, a natural sequence of events when one considers that the origin of the two sets of cells is the same.

FERRET, 13.5

Choroid Plexus.



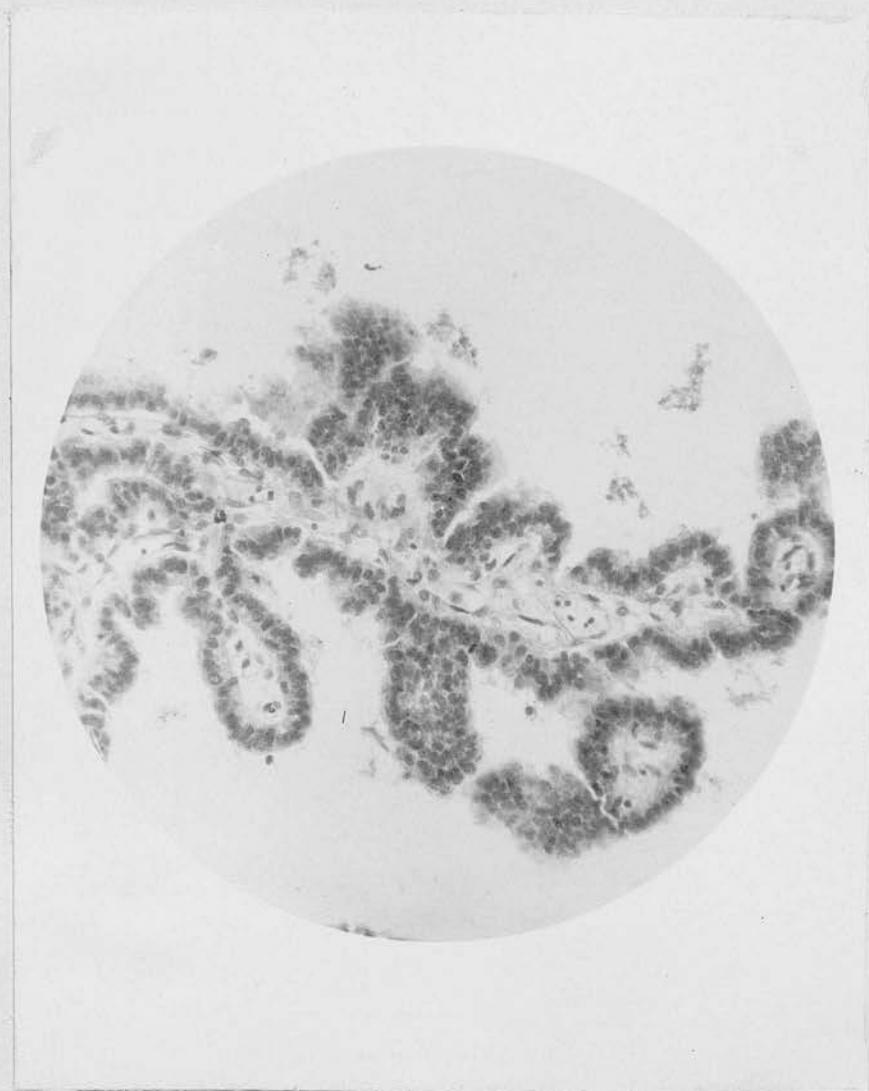
NOTE.

1. Early condition of plexus.
2. Choroidal cells columnar.
3. Relation to Foramen of Monro.

FERRET. 13.5 mm.

X 248.

Choroid Plexus.

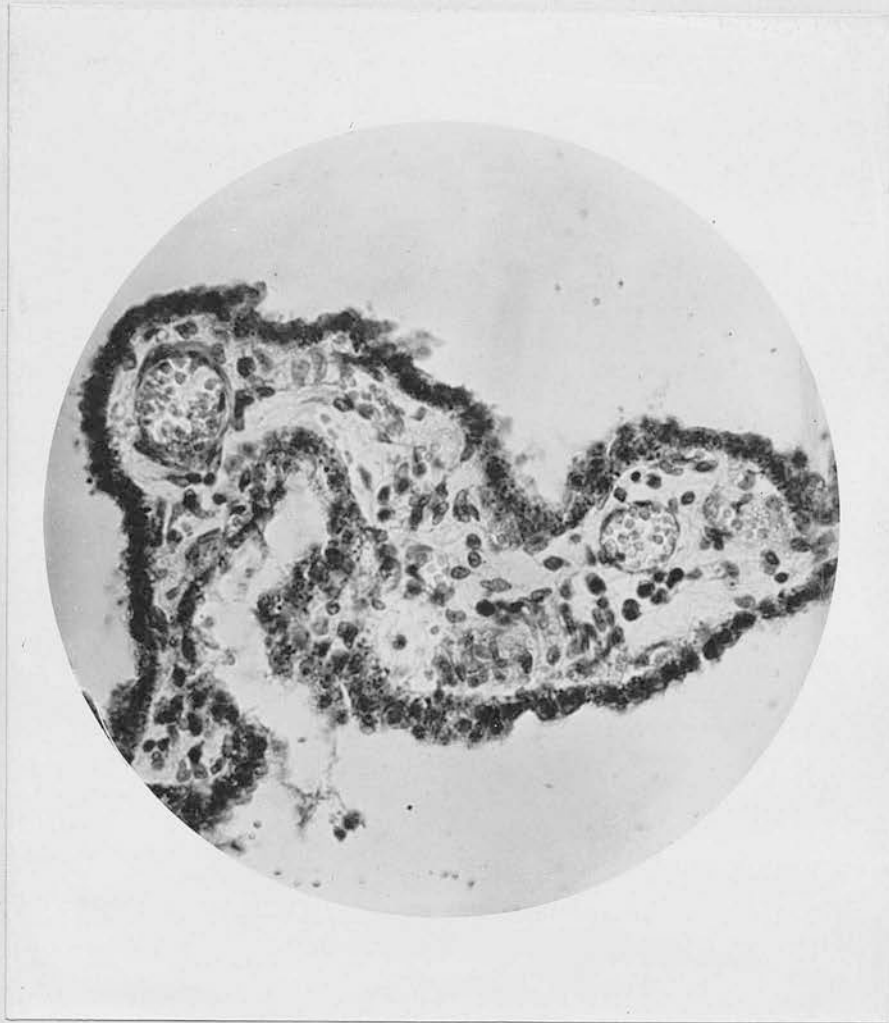


NOTE.

1. Plexus becoming convoluted.
2. Columnar Choroid Epithelium.

Adult FERRET.

Choroid Plexus.



NOTE.

Choroidal cells finally cuboidal.

Series of Cat Brains.

In a foetus of 12 cms. two sulci have appeared, the Calcarine Intercalary on the mesial and the Rhinic on the lateral surface. The cortex is already fairly well differentiated.

The cell lamination is as follows in the Neopallium :-

1. Molecular layer of fair width containing numerous cells disposed in an inner and outer layer.
2. Outer cellular layer composed of large well formed closely packed angular cells. The deeper cells of this layer are larger than the outer and together they form a very prominent band.
3. Intermediate reticular layer containing a large number of cells on the lateral surface but much better defined and opener on the mesial aspect. This open layer is specially well seen around the supero-mesial border of the hemisphere.
4. Inner cellular layer containing a mixture of large and medium sized cells of which the deeper are scattered in the outer part of the subjacent white matter.

The Rhinic Area shows a modified structure for the inner and outer cell layers described above have become much reduced and the intermediate layer is wider and opener.

Later Sections across the hinder end of the ventricle show that upper ends of the hemispheres gradually approach one another and become closely apposed, thus pushing the midbrain downwards, and in these vertical apposed surfaces the Intercalary fissure appears.

On the mesial surface the cortex is gradually narrowed
in/

in its lower part being pushed out by the mid-brain and the inner and outer prominent cell layers come together to form a narrow band of large pyramidal cells lying between the molecular layer and the ventricle. The cells of this layer are extremely well developed and send their processes out to the surface mostly. Finally this layer becomes interrupted and ends above and below in two recurved extremities. The portion of cortex just below the region of the developing Intercalary fissure which overlies the mid brain is opener in structure and the cells much scantier, and this is the position in which the fibres of the Corpus callosum gradually appear.

The Commissure is of considerable thickness and stretches outwards to become continuous with those fibres around the upper end of the ventricles.

On the lateral surface, and apposed portions of the Mesial surface the cortical structure appears to be essentially similar till the Rhinic fissure is approached.

Around the Calcarine Intercalary fissure and on the upper part of the lateral surface, the intermediate reticular zone between the inner and outer prominent cell layers is very distinct.

The cortical structure corresponds with that already given in general, the cortex can evidently be divided into three areas; an upper extending into the mesial surface to the Intercalary fissure marked by a clear intermediate layer, a middle portion where the cells are specially abundant, and a lower adjoining the

Rhinc fissure, where the cells are much scantier and the deep cell layer much reduced.

The Rhinc Area shows a modified structure. The external cortical cells are specially prominent, there is a reticular layer and the area between it and the lower end of the ventricle contains many cells.

The Ependymal Epithelium consists of short columnar or cuboidal cells and around the outer surface of the ventricle there is a thick layer of cells, increased at the upper end of the ventricle specially, whilst mesially this layer is extremely thin and consists only of one or two cells.

The Choroidal Epithelium covering the plexuses consists of very large columnar cells, cuboidal in places, and with extremely clear outlines.

In a Kitten two days after birth, the eyes still closed, the fissures are well developed, the Calcarine-Intercalary and Rhinic are deeper and the Lateral is present. The breadth of the cortex has increased, its subdivision is more complete, and the cells are better developed.

Mesially the same changes occur in the cortex which comes to lie under the Corpus Callosum, viz a gradual thinning and division into upper and lower portions. The cells are large and form two layers, the deeper cells being larger and more angular.

The Lateral cortex is divided into the following layers :-

1. The Molecular layer, containing a fair number of cells.
2. An outer thickly packed layer of cells, the outer small pyramidal, the deeper medium sized pyramidal cells set vertically mostly.
3. A layer of larger better defined pyramidal cells which stain better and have much more evident processes.
4. A broad layer of small irregular cells supported by a plentiful reticulum.
5. A layer of very large angular cells placed deeply.
6. A layer of small irregular fusiform or rounded cells containing a few larger elements, this layer lying upon the white centre and being variable in depth in different areas. At the bottom of the fissures this layer is greatly reduced and the large cells lie almost directly upon the Medullary centre.

The cortex lying between the lateral and Rhinic

fissures /

fissures is broader than that above.

The Ependymal Epithelium has become much reduced and is Cuboidal, whilst the cells around are much fewer, and the fibrous reticulum more evident.

Adult Cat.

Several specimens have been examined by different methods and the Cajal preparations have been most effective.

Near the extremity of the occipital area the cortical lamination appears to be essentially similar on both surfaces, but as the sections pass forwards, gradual changes occur and the appearance becomes complicated by the numerous fissures. Mesially there are two, the upper being the long and deep Calcarine-Intercalary, and the lower shallow and short sulcus being the Supra-splenic. Laterally, there are the Lateral, Supra-sylvian and Rhinic fissures.

The cortex on the mesial surface undergoes a gradual reduction in depth till finally it forms a prominent layer of extremely well developed pyramidal cells which belong to the Cornu Ammonis. When the Corpus Callosum appears it separates this structure from the gyrus fornicatus.

The Neopallial Cortex which extends from the gyrus fornicatus to the Rhinic fissure appears to conform throughout to a general type of cell lamination, with certain modifications in different areas. The cortex

of the gyrus marginalis is specially definite and may be taken as the type.

General type of Cell lamination :-

1. Molecular layer containing a few small cells.
2. Small pyramidal cells.
3. Medium pyramids.
4. Large erect pyramids with numerous processes which stain well, the apical passing out to the Molecular layer.

Taken together these three layers are of very considerable depth, and the cells are mostly erect.

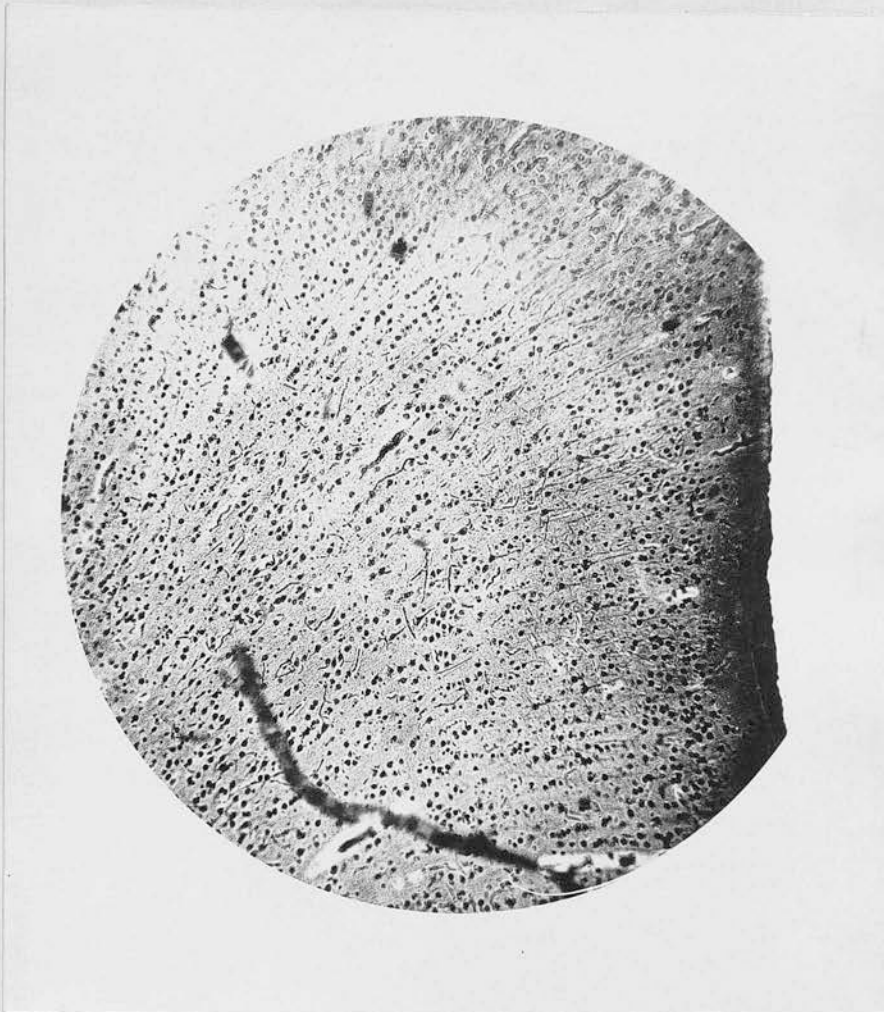
5. Layer of small irregular cells with abundant reticulum.
6. Layer of very large pyramidal cells, which form one of the most notable features of the cortex. The cells vary in shape and though mostly pyramidal with a very long apical dendron running outwards, they may be rounded with indefinite processes.
7. Layer of fairly large irregular fusiform or angular cells, with occasional large rounded or pyramidal cells scattered amongst them. At the bottom of the fissures the cells of this layer become flattened and elongated and lie parallel to the surface.

The cortex lying between the Lateral and Rhinic fissures is of a slightly different structure. It is deeper than that above and this appears to be due mostly to an increase of the small cell layers, especially the deepest, some of whose cells are of considerable size. The lamination is not so definite as in the upper area and near the Rhinic fissure there is a transition to

Adult CAT.

Cajal

Marginal gyrus.



NOTE.

1. Deep pyramidal layer.
2. Well developed layer of large vertical pyramids
beneath the small & medium.
3. General cell wealth.

the Rhinic type.

The Rhinic Area is also modified and this area extends from the bottom of the Rhinic fissure to the lower end of the ventricle on the mesial surface.

The Cortex is laminated as follows :-

1. The Molecular layer is very deep and contains numerous small cells.
2. An extremely prominent layer of medium or large sized pyramidal cells, scattered among which are some small pyramids, the cells being set irregularly.
3. An open reticular layer containing some scattered medium to large pyramidal cells.
4. A layer of cells corresponding to the deepest layer of the other parts of the brain, some of the cells being fairly large.

The Ependymal Epithelium consists of two layers of flat or Cuboidal cells. Outside it there is a plentiful reticulum of fibres and neuroglia.

SUMMARY.

As regards Cortical cell structure, in

1. the Embryo of 12 cms, the cells are arranged in three layers, outer, middle and inner beneath the Molecular layer. Of course the cells in these layers are not all of the same type and further subdivision might be made. The cortex varies in different parts

that /

that on the mesial surface undergoing a characteristic reduction in its lower portion. The upper portion which lies above the Corpus Callosum and surrounds the Calcarine Intercalary fissure is characterized by the clear area between the inner and outer prominent layers of cells and this arrangement persists around the upper border and upper part of the lateral surface of the hemisphere. The cortex between this and the Rhinic fissure is broader and the cells are more abundant, and the structure of the Rhinic area is also different. Hence at this stage the cortex shows, a subdivision which corresponds pretty closely to that found in the adult.

2. The brain of the newly born kitten presents no special features.

3. In the adult brain the cortex has become still further subdivided into six or seven layers and of these the most noteworthy are the outer and inner layers of large cells.

The cortex of the gyrus fornicatus is much reduced in depth, the superficial pyramidal cells are largely replaced by a migration outwards of the cells from the reticular layer.

The cortex of the gyrus marginalis which extends from the Calcarine-Intercalary to the Lateral sulcus possesses a characteristic structure, the large superficial and deep cells being specially prominent though apparently not peculiar to this area.

That cortex lying between the Lateral and Rhinic fissures is deeper, the cells generally being more

abundant /

abundant especially in the deepest layer.

The Neopallial cortex hence is capable of subdivision into at least three areas, whose limits are clearly indicated by the main fissures.

The Rhinic Area returns to the three layered structure, large cells being specially numerous peripherally, whilst the Molecular layer is very deep.

The Cells generally are well developed, particularly the larger pyramidal cells of the Neopallial cortex which possess numerous processes, the apical in all cases being most prominent and in some cases extending practically through the whole thickness of the cortex. Further these pyramidal cells are usually set vertically and send their apical processes outwards, and the surface layers are of considerable depth.

Visual Area. Working on homologies one is inclined to place the Visual Area in that portion of Cortex which lies between the Calcarine-Intercalary and the lateral fissures for the cortex on either side possesses a different structure. In other words, the Visual Area lies in the Marginal gyrus, which possesses a very definite type of cell lamination.

ADULT DOG.

The cortex of the occipital region of the dog presents several interesting features. The cortical depth is greater relatively than in the brains previously described, and it is arranged in a more complex manner. The most striking feature in the greater part of the Neopallial cortex is the presence of a superficial and a deep layer of very prominent large pyramidal cells which show a special affinity for the silver method of Cajal. The wealth of medullated fibres is also greater and their arrangement is also well brought out by Cajal's method. The fissures are also a little more complicated and on the mesial surface there are two, the lower being the long and deep calcarine-intercalary or splenial complex and the upper the supra-splenial whilst, in the lateral surface, the posterior ends of the lateral, supra-sylvian and Rhinic fissures are all well marked and there are in addition some shallow subsidiary sulci. The posterior extremity of the lobe calls for no special description and the detailed account given below is taken from sections near the hinder end of the corpus callosum.

The mesial surface of the hemisphere undergoes the same changes detailed in previous brains. The true mesial surface which bears the calcarine-intercalary fissure is relatively of greater extent and the lower part which lies in apposition with the mid brain is correspondingly reduced and the intervening corpus

callosum /

callosum is thicker.

The Neopallial cortex which extends from the calcarine intercalary sulcus to the Rhinic fissure may be divided into two areas by the lateral fissure.

The upper area which lies between the calcarine-intercalary and the lateral fissure and includes the large marginal gyrus presents the same cortical structure throughout.

The Cell lamination is as follows :-

1. A Molecular layer of moderate depth which presents no special features.
2. Layer of small and medium pyramidal cells, the larger lying deeply and the two sets together forming a fairly broad peripheral layer of cells.
3. Outer layer of large pyramidal cells which are set mostly vertically and stain very darkly, forming a very prominent feature of this region. These cells are not very abundant, are almost all pyramidal with a long apical process which passes straight out to the overlying layers giving off some horizontal collaterals on its way, whilst the basal processes are numerous and those which arise from the angles run either obliquely or horizontally.
4. Layer of small irregular angular cells of fair width supported by an abundant fibre reticulum.
5. Deep layer of large dark pyramids very similar to the outer large cells. They are almost all set vertically and possess very long apical processes which extend right out to the surface layers. The processes of adjacent cells run parallel to each other, thus giving

Adult DOG.

Cajal.

Marginal gyrus.

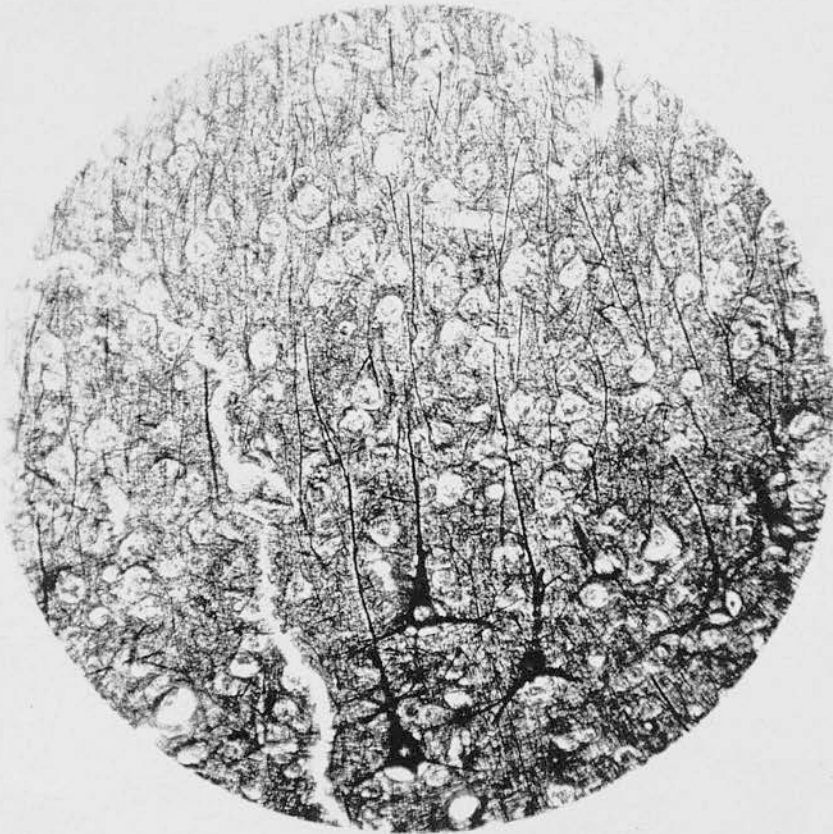


NOTE.

1. The superficial large pyramids.
2. The deep large pyramids.
3. Cortex very deep relatively.

Adult DOG.

Marginal gyrus.



NOTE.

I. Layer of large deep pyramidals.

a radially striated appearance to the overlying cortex and in their passage outwards give off numerous collaterals which pass off at right angles and help to form horizontal bands of fibres. These cells are scanty but their large size and numerous processes make up for their paucity of numbers. Their basal processes are long and many of them pass away horizontally from the parent cell.

6. Layer of small stellate irregular or fusiform cells of variable depth and much reduced at the bottom of the sulci. The most striking feature of this area is the presence of the external and internal layers of large pyramids which closely resemble each other though of course the apical processes of the deeper cells are very much longer.

The Lower Area. extends from the Lateral to the Rhinic fissure and its cortical structure is very similar to that above except that the outer large pyramids are almost entirely absent and occur only at wide intervals. At the same time the deep large pyramids are relatively more numerous. The cortex is perhaps relatively deeper owing to an increase of the small celled layers.

The Gyrus Fornicatus displays a special cell structure for in it the cortex becomes much attenuated towards the corpus callosum, the superficial small celled layer largely replaces the surface pyramids, and the individual layers fuse to a great extent. The large deep pyramids too, are replaced by smaller blunter cells with indefinite processes /

processes.

The Rhinic Area though relatively large calls for no special description.

The Visual Area probably lies in the gyrus marginalis which has a very distinctive type of lamination and a special development of superficial pyramidal cells of varying size. If this be so the area is a very large one for the marginal gyrus is both broad and long.

Series of Rabbit Brains.

This includes a 2 cm foetus, a full time foetus and the adult.

In a foetus of 2 cms The brain wall has the following structure, as displayed by sections across the posterior end of the ventricle :-

1. Narrow peripheral reticular layer (Molecular) containing some small round cells, and a deep layer of scanty fusiform cells lying parallel with the surface.
2. Narrow band of rounded cells, scanty in the upper part of the hemisphere, but increased below to form a very distinct layer.
3. Opener indefinite layer containing small cells.
4. Broad and prominent layer of large pyriform neuroblasts. Layers 2,3 and 4 are evidently a development of the original mantle layer, and the subdivision becomes more definite in the more anterior sections.
5. Ependymal layer formed of tall columnar cells set closely together, with nuclei at different levels.

The inner ends of these cells are placed upon a very definite limiting membrane, while the outer ends become tapered off and pass outwards among the cells of the outer layers, thus forming a supporting network.

Later sections show certain definite changes on both surfaces of the brain.

Mesially the Molecular layer becomes much broader and the other layers are more clearly differentiated.

Finally the brain wall becomes thinned and interrupted towards its lower part and the cell layers end above

and /

RABBIT, 2 cms.



NOTE.

1. Differentiation of brain wall well begun.
2. Peripheral cortical layer just beginning to appear in the lateral wall.

and below this gap in two thick recurved masses.

Laterally the brain wall varies in thickness above and below being much deeper below.

In correspondence with this fact the different layers of cells are much better defined below, the layer of large cells lying next the molecular layer being specially prominent, whilst the open layer beneath it is very broad and contains numerous small cells.

The Lower third of the lateral brain wall therefore presents a special structure, and probably corresponds to the hinder end of the Rhinic area.

The Cells, generally, belonging to the cortical layers at this stage are large rounded or pyriform neuroblasts and in the molecular layer there are special fusiform cells.

In a full-time foetus the structure is as follows :-

Early sections from near the end of the occipital lobe show that the hemisphere may be divided into upper and lower portions :-

The upper appears to have the same type of cortical structure on both surfaces though the cells form a much deeper layer laterally. The most striking feature is the presence of a deep layer of large deeply stained cells which ends abruptly above and below. The remainder of the structure calls for no special description.

The lower occupies the lower third or more of the hemisphere /

hemisphere, possesses a specially deep Molecular layer, and consists mostly of large pale closely packed cells. The boundary line between these two areas is very distinct and in later sections becomes even more so, thus delimiting the Rhinic and Neopallial portions. In sections across the hinder end of the ventricle further differentiation has occurred. The upper ends of the hemisphere approach and gradually become closely apposed above the mid-brain and future site of the Corpus Callosum.

Mesially the brain wall and the cortex lying in the outer aspect of the mid-brain become thinned. The cortex is reduced to a prominent layer of large pyramidal cells lying close to the ventricle and finally as the brain wall becomes interrupted by the formation of the Choroidal fissure ends above and below in recurved extremities. The portions between the upper of these and the two apposed surfaces is fairly broad, several cell layers are present and it marks the site of the future Corpus Callosum.

The Rhinic fissure is faintly marked on the surface and marks a change in cortical structure. The cortex on the apposed mesial surfaces and lateral surface and lower borders of the hemisphere differs in structure and can be divided into two parts which become more clearly demarcated as the sections pass forwards.

I. From the mesial surface, round the superior border and for rather more than the upper half of the lateral surface, the cortex presents a characteristic structure and is subdivided into the following layers :-

1. Molecular layer of average width.
2. Layer of small pyramidal cells.
3. Layer of medium pyramids. These two layers may quite well be considered as one.
4. Broad layer of small, closely packed irregular cells.
5. Broad layer of specially large pyramidal cells some of which stain very darkly. They are mostly set vertically and send their apical processes outwards. This layer and especially the darkly stained cells are characteristic of this area for the large dark cells come to an abrupt end on the apposed mesial surfaces above, and below end at some distance from the Rhinic fissure.
6. Clear reticular narrow zone containing a few small cells.
7. Broad layer of medium sized, irregular cells lying upon the white centre, amongst which there are occasional large pyramidal cells with outwardly directed apical processes.

II. Intermediate Area lying between the lower end of (I) and the Rhinic area.

In this the cortical structure above described is modified as follows :- The cells do not stain so well, the layer of small cells is deeper and the large celled layer is set directly upon the deepest layer, without the intervention of the clear reticular zone seen above. The specially large dark cells of the upper area are absent.

The Rhinic Area extends from that fissure to the lower border of the hemisphere: At first it is very

thick /

thick and the cells are arranged into a broad outer layer of small medium and large angular cells, the large being most abundant, and a narrow inner layer of smaller cells separated by an intermediate reticular area.

Later the area becomes much reduced but the layers can still be defined and the large cells predominate. The Molecular layer is very deep.

Adult Rabbit.

Several specimens have been examined and different details are brought out by different methods, Cajal preparations being most instructive.

Early sections, near the tip of the occipital lobe show that the cortical structure is essentially similar on both surfaces of the brain but mesially the cortex is much narrower and the different layers are much reduced. The hinder end of the Rhinencephalic area shows a modified structure and occupies about the lower fourth of the hemisphere, being separated above from the Neopallium by the Rhinic fissure which is the only one present in this region of the brain.

Later sections, advancing into the lobe and cutting across the ventricle present a better defined structure well worth detailing.

Mesially the cortex soon becomes divisible into three areas, 1, Upper, which as the upper ends of the

hemispheres /

hemispheres come together, comes to lie between the Corpus Callosum and the superior border in close apposition with its fellow of the other side.

2. Middle, very broad at first but gradually reduced. It at first possesses the general structure but is finally reduced to a fairly wide area containing scattered large pyramidal cells, placed under the Corpus Callosum.

3. Lower extensive area passing almost to the lower border. Between this and the ventricle there is a large clear zone, in which there appears a band of very large vertical pyramidal cells which gradually extends up and down, placed near the ventricle, and covered by a very deep Molecular layer. The mid-brain gradually pushes this area outwards and thins it so that it finally becomes interrupted to admit the Choroid plexus. The prominent cell layer then ends above and below in the characteristic manner ^{already} described and one must comment upon the great size of the cells of this layer, on the fact that they are set vertically and send their apical processes right out to the surface. These large cells belong to the Cornu Ammonis.

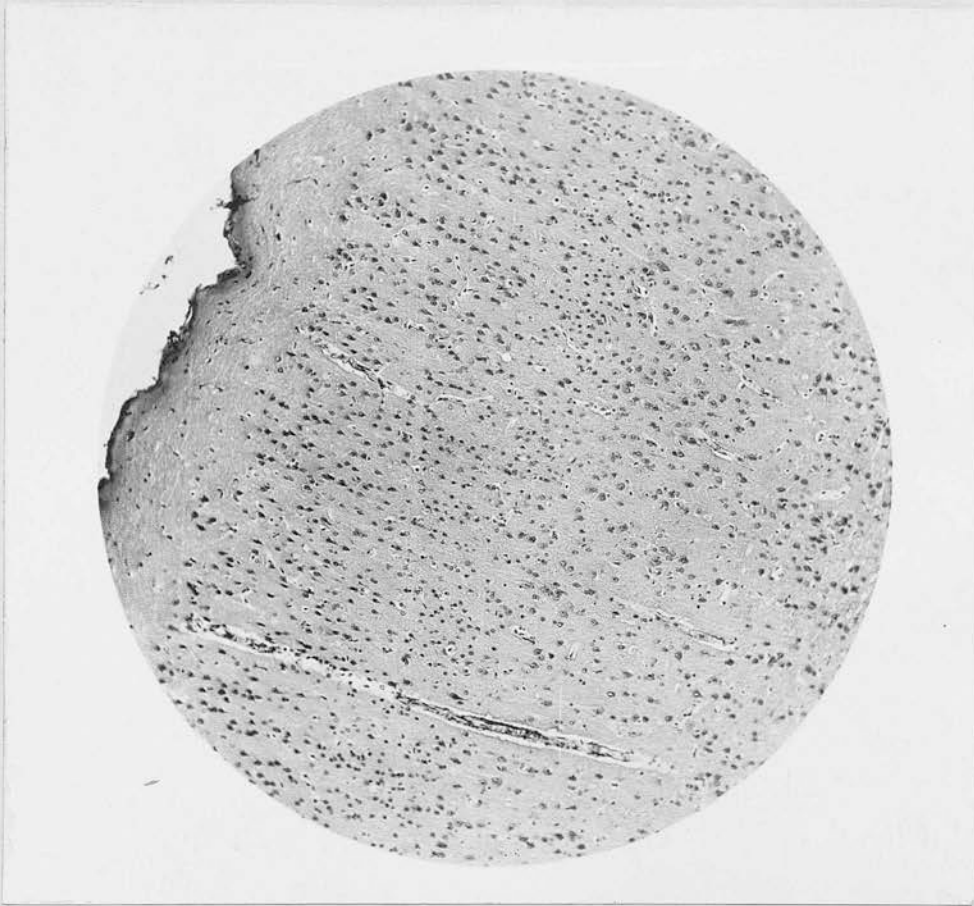
The Neopallial cortex calls for special description and can be divided into three areas :-

Area I, which extends from the superior border down to a short distance above the Rhinic fissure. This cortex has the following lamination :-

1. A Molecular layer of ordinary type.
2. Layer of small and medium sized pyramidal cells with occasional large pyramids.

Adult RABBIT.

Lateral Cortex.



NOTE.

1. Lamination very distinct.
2. Deep pyramid cells relatively abundant.
3. Superficial pyramids mostly medium.

3. Broad layer of small irregular or angular cells.
4. Fairly deep layer of very large pyramidal cells which forms the most notable feature of this area of cortex. Cajal preparations display these cells particularly well and show that they are nearly all elongated pyramids placed vertically. Several short processes arise from the base and the apex is prolonged into a dendron of great length which passes right out to the surface layers. These dendrons run a straight course, show numerous fine varicosities and taken together give the cortex a marked radial striatum. They give off numerous collaterals which help to form bands of fibres running parallel to the surface.
5. A narrow but distinct open reticular layer containing scattered small cells.
6. Broad layer of small and medium sized irregular cells, some spindle-shaped, others pyramidal with occasional large pyramids which send their apical processes outwards for a considerable distance.

Area II, which lies between the lower end of the previous one and the Rhinic fissure.

In this the peripheral pyramidal cells are not so numerous, and the outermost are specially prominent being large and deeply stained, the large cells placed deeply do not stain so well and are less definite, and the reticular layer beneath is practically absent, and the whole brain wall is thinner.

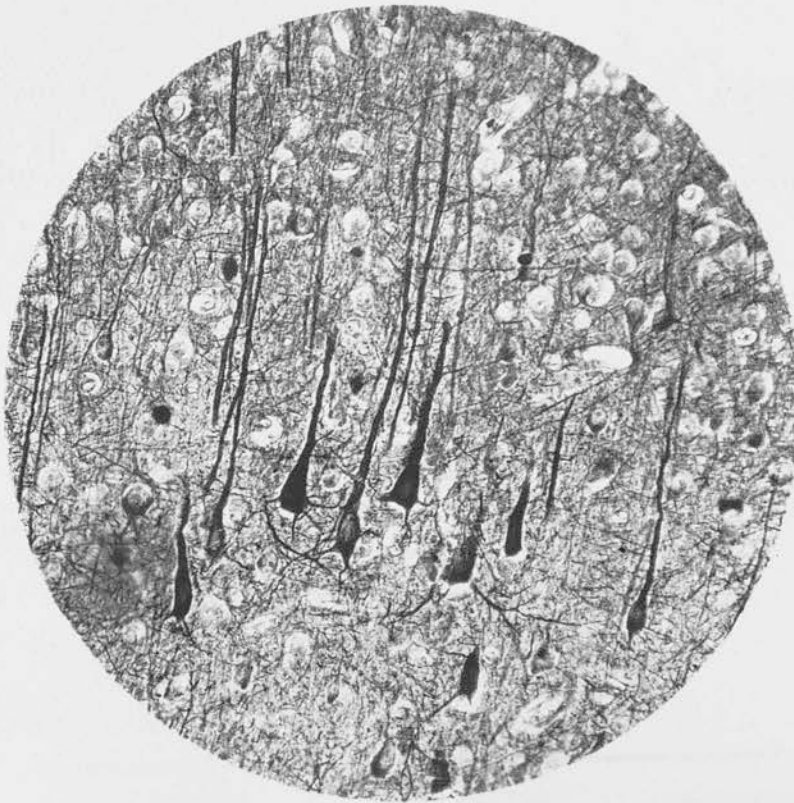
Area III. The apposed mesial surface. In this the cortex is much reduced, the cells are smaller and the layers fuse considerably.

Adult RABBIT,

X 282

Cajal

Lateral Cortex.



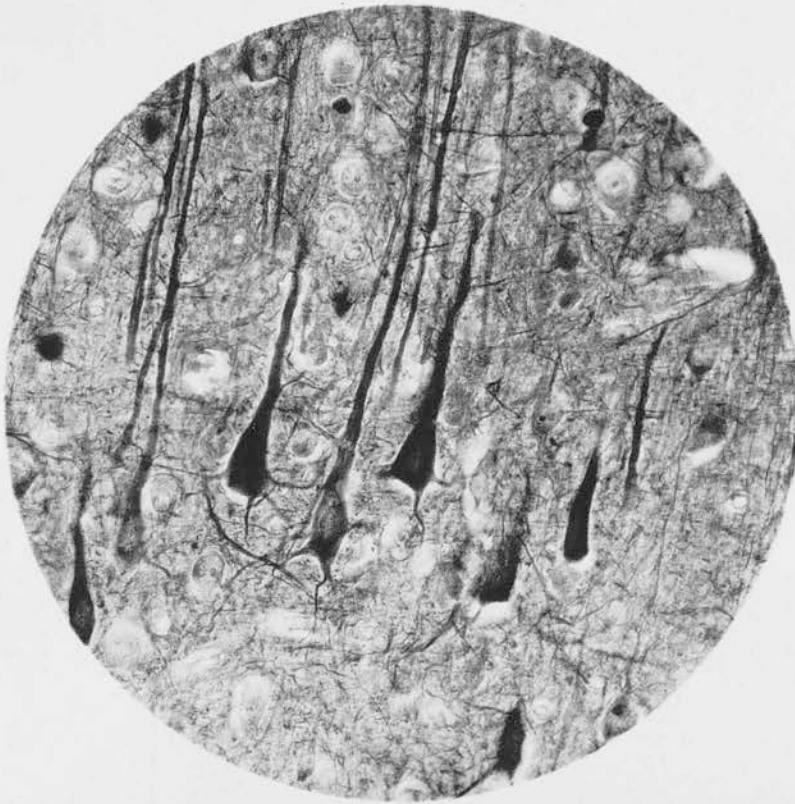
NOTE.

I Large deep pyramidal cells - their erect position and their prominent apical processes.

Adult RABBIT, X 460.

Cajal

Lateral Cortex.



NOTE.

1. Same cells. High power.

Adult RABBIT.

Cajal.



NOTE.

- I. The corticopital apical processes of the large deep pyramids

The Rhinic Area which extends from the fissure to the lower border and ends on the mesial surface, presents special features.

1. The Molecular layer is very deep.
2. The outer cell layer consists of large darkly stained pyramidal cells set quite irregularly. These cells show a marked tendency to be aggregated into small clumps, a point noted in this area in other brains.
3. A broad band of scattered small and medium sized cells.
4. A clear reticular layer in the middle of which there are a few very large pyramidal cells evidently corresponding to the layer of similar cells in the rest of the cortex.
5. A fairly deep layer of medium and large cells set quite irregularly.

The large size of the cells in the Rhinic area is very striking.

The Ependymal Epithelium consists of one or two layers of flattened or cuboidal cells.

Around the ventricle there is a zone of fibres, broader externally and scanty mesially, in which the fibres are wavy and run parallel to each other, passing off from the upper end of the ventricle to become continuous with the fibres of the Corpus Callosum.

The Choroidal Epithelium consists of a layer of Cuboidal cells very different from those of the Embryo.

SUMMARY.

1. The brain of the 2cm fetus as might be expected from the shorter gestation period of the rabbit, shows a much greater degree of differentiation than sheep or pig embryos of the same length. The cortex is already subdivided and the upper and lower parts of the hemisphere differ in structure, thus probably indicating the division between the Neopallium and Rhinencephalon.

2. The full time brain presents the same general features as the adult, but the cells are not so well developed and dark staining fibres so prominent in the adult are wanting.

3. The adult occipital region presents some well marked characters. The Neopallid cortex has in great part become divided into six or perhaps seven very distinct layers and of these the most outstanding and characteristic on the lateral surface is the deeply placed layer of large pyramidal cells. One must comment specially on these cells for they are the most remarkable present in this area. Their vertical position, size and processes, notably the apical dendron which extends right out to the surface are very striking. The radial striatum produced by these fibres is also very marked.

Mesially on the surface in apposition with the mid-brain the most notable feature is the narrow band of very large pyramidal cells which lie close to the ventricle. These also possess very long apical

dendrons /

dendrons which pass outwards and produce a marked radial striatum of the overlying Molecular layer. Hence we may say that the most outstanding feature on both mesial and lateral surfaces is the presence of a layer of very large vertical cells and mesially it comes to be the only one ^{while} laterally it is one of several layers.

The Rhinic Area presents a special structure, the most prominent features being the predominance of large cells set irregularly, the tendency of the outermost cells to form clusters, and the deep molecular layer.

The Visual Area. There is no trace of a Calcarine fissure to which to relate it, and moreover the cortex of the apposed mesial surfaces of the hemispheres is so poorly developed that it is unlikely to be connected with the visual function. The Visual Area hence probably lies entirely on the lateral surface, in that extensive area of cortex in which the laminated structure is so definite.

Adult Guinea pig.

This is a smooth brain and the chief sulcus visible in the posterior part is the Rhinic, placed near the lower border of the hemisphere. A very faint depression externally and a change in structure internally probably mark the position of the lateral fissure not far from the upper border.

Calcarine-
The intercalary fissure is absent.

The Neopallid cortex presents certain features of interest and is capable of division into areas characterized by some modifications in structure and the further forwards the sections pass, the better marked does this become.

On the Mesial surface

as the sections pass forwards gradual changes occur. The essential point in these is the disappearance of the superficial pyramidal cell layers of the cortex and the predominance of the large cells of the 5th. layer, which cells go to form the prominent cornu ammonis. The corpus callosum appears and comes to separate the true mesial surface of the hemisphere from the part below, which is closely applied to the Mid brain. This lower part is finally thinned and interrupted to admit the Choroid Plexus to the Ventricle.

The Neopallid Cortex

which extends from the corpus callosum to the Rhinic fissure is divisible throughout into six layers but there are well marked differences in

different /

different areas in the individual layers.

The general type of Lamination is as follows :-

1. Molecular layer of average depth and possessing two types of cells, the larger and scantier lying superficially.
2. Layer of small pyramids.
3. Layer of medium pyramids.

These pyramidal cells are set mostly vertically and send their apical process out to the surface . Taken together they form a layer which varies considerably in depth at various levels.

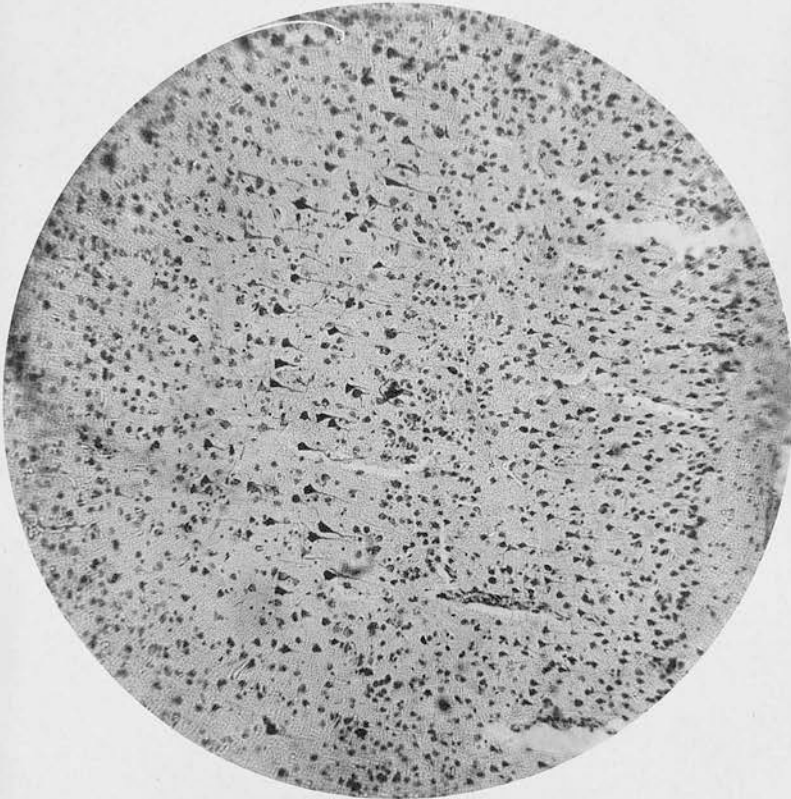
4. Fairly broad layer of small round and spindle cells mixed with larger irregular cells whose processes stain feebly.
5. Layer of large pyramidal cells. This is an extremely well marked layer throughout the cortex, and its cells are easily the most prominent. They are fairly numerous, are set quite vertically and send their long apical processes outwards amongst the superficial layers of smaller pyramids, giving off collaterals on the way. These cells lie amongst an abundant reticulum, contained some small poorly defined irregular cells, and the layer forms the most striking feature of the Neopallic cortex.
6. Broad layer of irregular angular cells scattered amongst numerous spindle cells of variable depth and blending deeply with the medullary centre.

The cortex extending from the level of the

corpus /

Adult Guinea Pig.

Lateral Cortex.



NOTE.

1. Lamination very distinct.
2. Six layers. well seen.
3. Abundant large deep pyramids.

corpus callosum to the Rhinic fissure may be divided into three areas by certain differences in the several layers.

- I. That lying on the Mesial surface and extending from the Commissure to the Supero-Mesial border of the hemisphere. The surface pyramids change their type and tend to be replaced by the less well defined cells of the fourth layer. The cells are mostly fusiform and stain poorly.

The large pyramids are very scanty and are replaced largely by badly defined pale cells.

It will be seen therefore that fusion of the primary layers tends to occur, and that the total depth of the cortex is reduced. This area of the cortex is of a more rudimentary type than that on the lateral surface.

- II. An area extending from the superior border to near the middle of the outer surface.

In this the different layers are extremely clearly defined, owing to the depth of the fourth small celled layer, and the large size of the giant pyramids beneath.

The superficial pyramids together form a fairly broad and well defined layer.

- III. Area lying between II and the Rhinic fissure.

In this the lamination becomes less definite. The superficial pyramids are greatly reduced though somewhat larger. The fourth layer is deeper but the cells are not uniform. The large pyramids, at first abundant, become more

irregular /

irregular and stumpy and near the Rhinic fissure are fusiform. The whole area is characterized by a lack of definition.

The Rhinic Area

conforms to the general type in the predominance of a surface layer of large irregular darkly stained cells arranged quite irregularly and tending to become clustered.

Near the Rhinic fissure above and below there is a gradual transition between the adjacent areas.

SUMMARY.

The cortex of the guinea pig conforms generally to the type in allied orders.

The large pyramids of the 5th. layer form perhaps the most striking feature of the Neopallic Cortex in virtue of their size and the length of the apical process but their predominance in the Cornu ammonis indicate that they are not of recent evolution.

The Visual Area

It has been noted that the intercalary fissure is absent and that the cortex on the apposed mesial surface is more primitive than that in the lateral. It would seem likely therefore that the visual area lies entirely on the lateral aspect of the hemisphere, probably in Area II, in which the cortical lamination is so well defined.

It is in this area that the superficial layers of pyramidal cells are most clearly defined.

Adult Mole.

Specimens have been examined by different methods and the results are very interesting, though, as might be expected the structure is very primitive. The external surface of the brain is smooth and the only fissure present in the hinder end is the very faint groove indicating the position of the Rhinic fissure. As will be noted later the histological differences between the Rhinic and Neopallial cortex are well marked.

The Cerebellum is wedged in between the occipital lobes and will appear in micro-photographs of the posterior portions of the lobes.

Passing into the detailed description of the histology of this brain one observes that in sections near the tip of the occipital lobes, the cortex differs on the mesial and lateral aspects very markedly.

Mesially, the cells are much more numerous and are closely packed to form a narrow peripheral layer lying beneath the molecular layer. The cells are irregular, medium sized, and their processes stain poorly. Lying in the white centre between this layer and the site of the future ventricle there are a number of scattered, well developed and multipolar cells with very definite processes, the apical processes being in most cases directed outwards. The area containing these cells does not extend through the whole length of the mesial surface but lies mostly in its lower half. Above and below the peripheral layer alone is present but is

rather /

rather wider.

Laterally the cortex consists at first of a narrow band of darkly stained multipolar cells larger than those in the peripheral layer mesially. The cell processes are not very evident and the cells are set quite irregularly.

This layer very soon becomes deeper and the cells extend inwards towards the centre of the section and are scattered through the white centre.

At the lower border of the brain the cells become larger and the processes more evident, thus forming a very prominent collection of cells in what is probably the posterior end of the Rhinencephalic area. At the upper border, the structure is less definite and consists simply of the mesial and lateral cortex and scattered cells lying in the white centre between. This difference between the two borders of the hemisphere is very well marked.

Sections a little further forwards across the tip of the ventricle show that a re-arrangement of the cell structure has occurred.

Mesially, the peripheral cell layer described above has disappeared in about its middle third, and its position is occupied by some darkly staining masses, possibly neuroglia. The large and well developed cells of the deeper layer have become more numerous and more definite and send their apical processes outwards towards the molecular layer.

Laterally also advances have occurred and the cortex extends practically through the whole depth of the brain wall.

The Cell Lamination has become well defined and consists of six layers:-

1. Molecular - comparatively narrow and calling for no special description.
2. A narrow layer of fairly large multipolar cells of variable size, set quite irregular, and possessing short and scanty processes.
3. A broad open layer containing small scattered cells lying in an abundant reticulum.
4. A layer of large angular cells like those of the outermost layer but relatively much larger and scantier.
5. A deep open reticular layer containing only a few small cells.
6. A layer of small fusiform cells set mainly parallel to the surface.

Circumferential fibres are very prominent and form a thick network round the ventricle.

Cortex of the above type extends from the supero-mesial border of the hemisphere down to the Rhinic fissure.

On the apposed mesial surfaces the cortex is thinned and the cells are scantier and smaller. Whilst laterally the Rhinic area is clearly marked off by a change in structure.

The more anterior sections show that a re-arrangement of structure gradually takes place on the mesial surface.

The layer of cells gradually becomes narrowed to form an extremely prominent band which corresponds in extent to the ventricle.

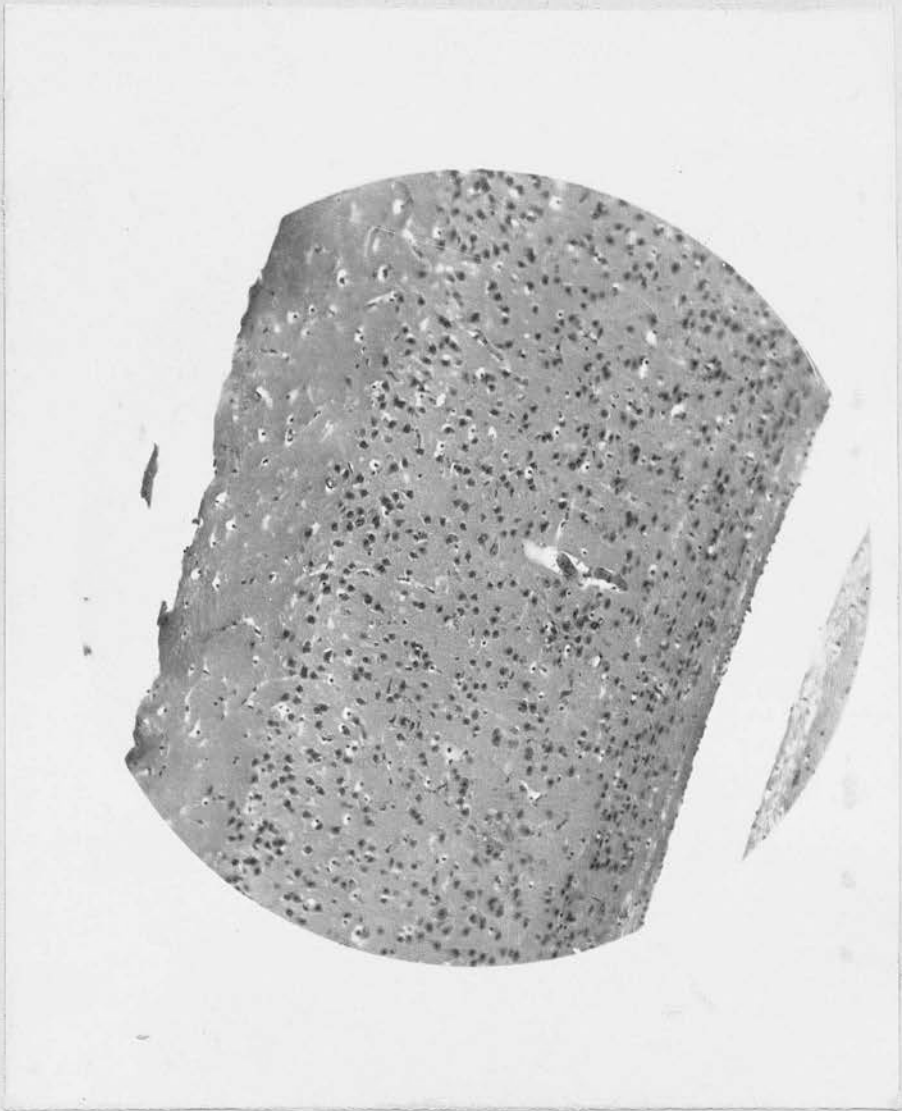
The cells are flask shaped or pyramidal, with large

well /

MOLE.

Outer wall.

Whole thickness.



NOTE.

1. Poor cellular wealth.
2. Lack of pyramidal cells.
3. Cortex extends through almost the whole thickness of the brain wall.

well stained bodies containing oval nuclei and prominent nucleoli. The apical processes are very long, give off a few collaterals and extend right out to the surface, parallel to one another, thus giving the outer part a radial striatum. The basal processes are short and scanty and ramify amongst the deeper cells of the layer. These large cells are several deep and lie upon some deeper rounded or irregular smaller cells. They are better defined below and become smaller and more abundant above where the layer thickens and ends opposite the upper end of the ventricle. At this stage a rod-shaped band of small and granular cells enclosed by a molecular layer has appeared between the mid-brain and the mesial brain wall. This band becomes progressively larger and a clear area appears in its centre. Later it becomes triangular and consists of small closely packed dark granular cells, which surround a clear reticular area in which there are a few large angular cells. These steadily increase and become re-arranged. The original granular layer disappears first on the surface next the mid-brain and then on the surface applied to the hemisphere. In this way the large central cells approach the prominent cell layer in the mesial brain wall and finally become continuous with it. The layer then becomes divided into upper and lower recurved and expanded ends between which the brain wall is thinned to admit the invaginating choroid plexus. These structures on the mesial wall of the hemisphere evidently form the cornu Ammonis, which is characterized

Adult MOLE.

Mesial & Lateral walls.

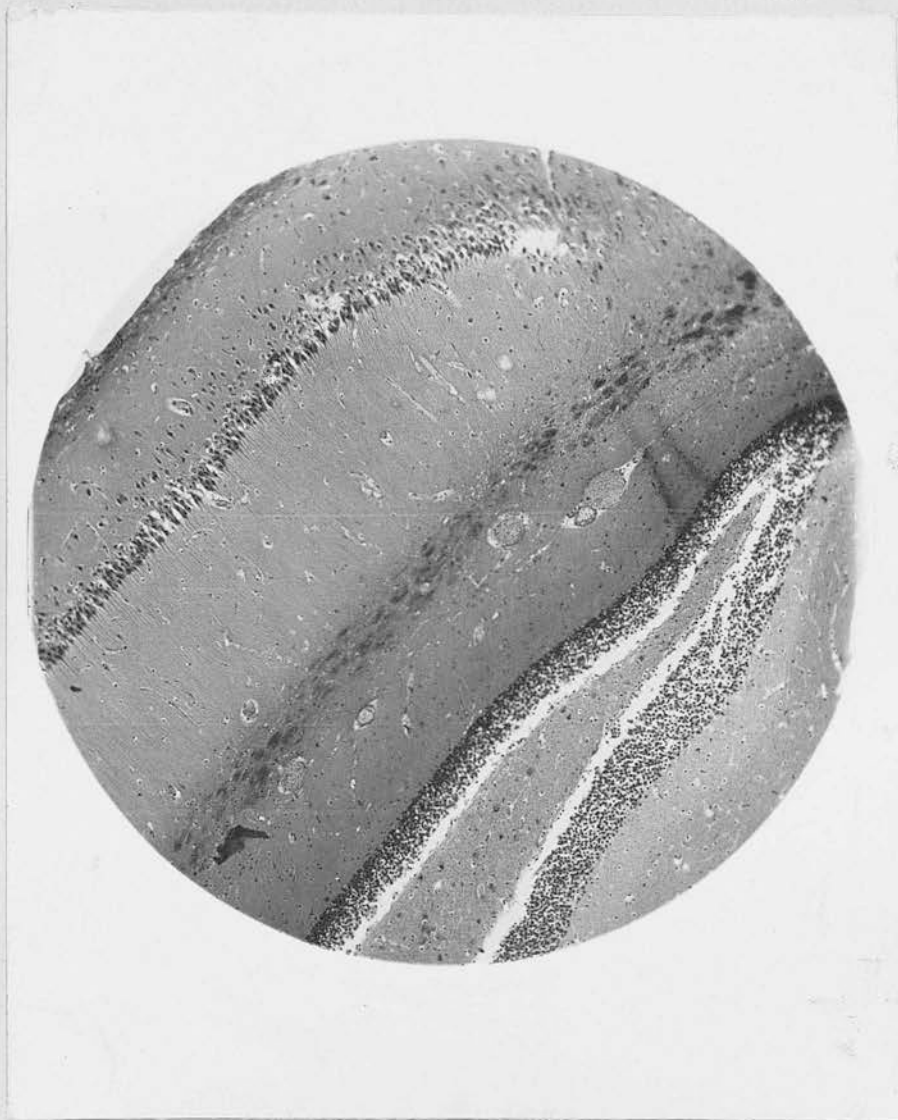


NOTE.

1. Their different appearance.
2. Elongated granular celled structure mesially.

MOLE.
Mesial wall.

Cornu Ammonis

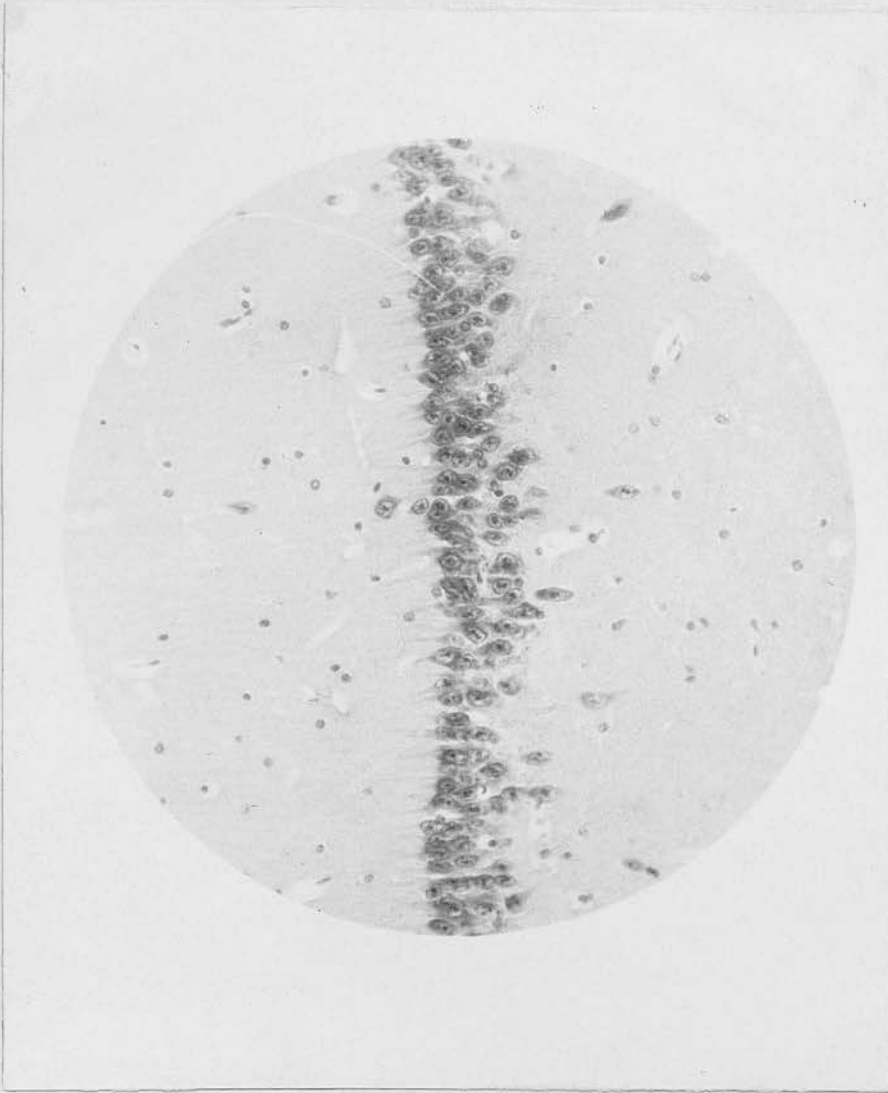


NOTE.

1. Single layer of large cells with super-jacent striation.
2. Granular celled structure mesially.

Adult MOLE.

Cornu Ammonis



NOTE.

1. Single layer of large cells.
2. Radial striation of super-jacent part.

by the large size of its cells.

The Corpus Callosum appears as a fairly broad band of transversely running fibres connecting the two hemispheres and the fibres become continuous with those encircling the ventricle.

The Rhinic area gradually becomes clearly marked off from the Neopallium, externally by a faint fissure and internally by a change of structure.

Towards the lower limit of the Neopallium the outer cortical cell layer becomes less definite, and then suddenly the cells become more numerous, stain better and have more definite processes. This prominent layer extends round the lower border of the hemisphere to become continuous with the lower end of the cell layer in the mesial wall. There are some very large multipolar and fusiform cells remarkable for their size and clear outline, scattered between the peripheral layer and the ventricle.

The Ependymal Epithelium is extremely small and the cells are poorly marked off from one another. They are mostly flattened but cuboidal cells occur in places.

The Choroid Plexus consists of a system of convoluted extremely thin walled blood vessels, covered by a double layer of epithelium. The inner layer consists of short cuboidal cells, with dark round or oval nuclei and the outer layer of flat cells with elongated nuclei.

Summary.

As might be expected from the position which this animal occupies in the mammalian series, and living as it does partly underground and a hibernating in season, the brain of the mole shows a low degree of development.

1. The most striking feature in the portion of the brain examined is the remarkable layer of cells present upon the mesial surface. These cells are extremely well developed comparatively and their apical processes extend right out to the molecular layer at the surface, giving off a few collaterals on the way. In fact, practically all the well developed cells on this surface of the brain are placed so that their bases look towards the ventricles and their apical processes are directed to the surface. On the lateral surface

the /

the cells are set quite irregularly and this a well marked point of difference between the two surfaces of the brain. Their size, prominence and high degree of development especially of the apical processes make one think that this cell layer in the mesial surface must subserve a special function. They belong to the cornu ammonis and are concerned in the olfactory sense. These large cells are therefore characteristic of the older part of the brain. The more anterior sections show that this layer of cells comes to lie beneath the corpus callosum but from this point onwards it appears to diminish in importance, becoming divided, and much reduced whilst the cells themselves are fewer and less prominent.

Further reference will be made to this later.

2. The lateral wall of the brain shows practically no separation into cortex and white centre for the cells extend throughout its whole thickness. They can be divided into five layers of which the external, middle and internal possess the largest cells. The deepest cells outside the ventricle are mostly placed parallel to its surface, whilst the cells of the other layers are placed quite irregularly.

3. The upper ends of the hemispheres which are of apposed to each other above the corpus callosum show a less definite structure than the lateral surface for the cells are fewer, stain more faintly and are perhaps a little smaller. This area which is the site of the calcarine fissure or splenial complex in higher types of brain is quite smooth and there is no special

modification /

modification of cell structure and one is not inclined to allot any special function to it.

4. The Rhinic area is even in the earliest sections clearly marked off from the Neopallid cortex, and this becomes more definite in the more anterior sections. It is characterized by the large size and dark staining of its cells.

5. The cells generally do not show a great development of processes and in most cases possess only apical, and two or three basal processes in the case of the multipolar cells.

6. The extremely narrow layer of superficial angular cortical cells is worth noting as indicating the primitive type of brain.

Early Development of the Occipital Cortex
in the Human Embryo.

- I. The youngest specimen examined was estimated to be about 23 days old and was 4.5 mm. long. The hemispheres are as yet unformed and the neural tube displays a very primitive structure, the wall consisting of a thick layer of closely packed dark staining neuroblasts enclosed between an internal and external limiting membrane. The thickness of the neural tube is greatly reduced dorsally and ventrally.
- II. The next specimen was estimated to be about the end of ^{33mm long} the 2nd. month and really forms the starting point of the series. The structure of the brain wall in the occipital region corresponds very closely to the description given by His in his "Development of the Human brain in the Early months" and consists of the following layers from within out.
1. Epithelial layer, the bases of the cells being separated from the Ventricular cavity by a very definite Int. Limiting membrane. Amongst these cells are numerous large rounded cells (the Keimzellen of His) which are evidently undergoing very active mitosis, as they show the figures very well.
 2. Cellular or Mantle layer which consists of a broad zone of closely packed darkly stained young nerve cells, which at this period are rounded or pyriform with a short pointed process arising from one pole. These cells are very numerous and are supported by a fairly abundant mature, and they constitute the most important element /

element of the brain wall at this stage, and in the later stages of development will be shown to undergo certain very striking changes, finally coming to form in great part, the grey cortex of the adult.

3. Peripheral Reticular layer which is built up of a coarse reticulum of fibres with a few small cells scattered through it. These cells are of a different type from the Neuroblasts of the mantle layer and His believed them to be glia cells.

Between this outer reticular layer and the Mantle layer there is a narrow and indefinite stratum containing a few neuroblasts which have evidently wandered out from the deeper layer of cells, and His describes this as a definite fourth layer in the 2 months foetus, under the name of the 'Zwischen Schicht'.

On tracing the sections forwards into the hemisphere certain changes occur on both surfaces. Near the posterior extremity of the ventricle the brain wall is of about equal thickness on both surfaces but further forwards the middle portion of the mesial wall becomes much thinned and consists simply of the Epithelial layer and a thin layer of Neuroblasts. Between this thin portion and the lower pole of the ventricle there gradually appears an oval cellular mass which projects into the ventricular cavity and evidently represents the rudiment of the Basal Ganglia.

The thinner portion gradually becomes invaginated into the cavity of the lateral ventricle by a large thin walled blood vessel which descends from above in the interval between the mid-brain and the hemisphere.

This invaginated portion which constitutes an early stage of the Choroid Plexus is at first a short process with an expanded extremity which has a wavy outline, and the point of entrance lies opposite the upper end of the Foramen of Monro.

On the lateral surface the 'Zwischen schicht' becomes more distinct as the sections pass forwards.

III. A foetus at the beginning of the 3rd. month ^{7 cms. long} shows a very definite advance in brain structure, for the whole wall is thicker and the outer cellular layer which is later to develop into the cortex is very definite. The cells have by this time advanced from the pyriform neuroblastic stage and are mostly bipolar. The layers of the brain wall from within out are :-
(following His.)

1. Matrix layer with the round 'Keimzellen' lying around the ventricle. The term "matrix" includes the Epithelial cells lining the ventricle and a fairly broad band of closely packed bipolar cells which correspond to the deeper portion of the mantle layer described in the previous specimen.
2. 'Zwischen Schicht' which is divided into an inner cellular part and an outer reticular part containing scanty cells and formed mostly of tangentially running fibres.
3. Peripheral Cortical Cellular layer which forms a narrow but very definite layer which is best marked on the lateral surface, whilst mesially it becomes gradually attenuated towards the lower border of the hemisphere.
4. Peripheral reticular layer (velum marginale) in which there are now numerous cells. From now onwards

this /

118

this will be spoken of as the Molecular layer, and it together with the subjacent band of cells constitutes the very definite though elementary cortex of the foetus at this stage, and is the most important division in the brain wall.

In the later part of the 3rd. month all these changes become more distinct and the cells of the cortical layer become more numerous owing to the emigration outwards of numerous cells from the matrix layer.

IV. A foetus in the 4th. month 16 cms. shows a great advance and the condition present more closely resembles that in the adult, and the Calcarine fissure is now very well formed, and the changes may be mentioned briefly.

1. The cortical layer of cells has steadily increased in depth and is fully twice as deep as in the early part of the 3rd. month. As yet there is very little sign of this important layer being differentiated into sub-laminae, but the cells in the outermost part beneath the molecular layer are more closely packed and form a broad darkly stained zone. Beneath this there is a slightly opener layer in which the cells are not so abundant, and lying deepest of all there is another zone in which the cells are closely packed but do not form such a dense layer as externally. This arrangement is fairly well marked on the surface just above the Calcarine fissure, but at the bottom of the fissure the cellular cortex is much reduced.

2. The Intermediate layer or 'Zwischen schicht' has become broader and forms the white or medullary centre and consists of fibres and numerous small cells.

3. The Matrix layer has become subdivided and according
to /

to His forms 5 layers but as these are of minor importance they need not be detailed.

I have dealt merely with the differentiation of the brain wall of the occipital region, from the earliest stage up to the time when a well formed but as yet undifferentiated cortex appears.

The changes which occur subsequently in the cortex up to the stage of full development, and the formation of the characteristic Human Visual Cortex about the Calcarine fissure in the 5th. and 6th. months, have been so fully worked out and figured by Shaw Bolton and Brodmann that it is unnecessary to go further.

The early developmental stages will be seen to correspond very closely with those previously described in the various series of lower animals. The subsequent changes are co-related with the increase in size and importance of the occipital lobe and the specialization of its cortex.

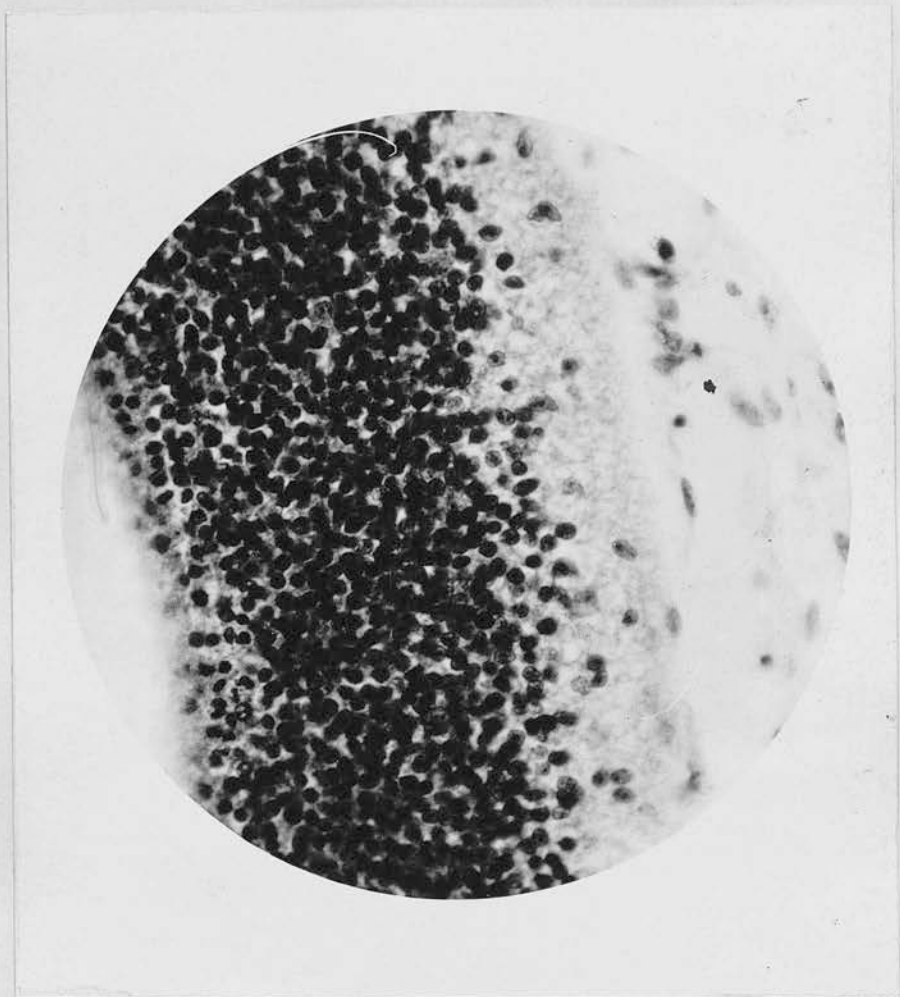
HUMAN, 4.5 m.m.



NOTE.

1. Very early stage of Brain wall.
2. Large pyriform Neuroblasts.
3. Occasional germinal cell lying just outside the ventricle, showing mitosis.

HUMAN. 30 mm.



NOTE.

1. Peripheral reticular layer.
2. Prominent Mantle layer.
3. Ependymal cells not very distinct.

HUMAN . 40mm.



NOTE.

1. Calcarine fissure well marked.
2. Differentiation of Brain wall well defined.
3. Cortex represented by the prominent peripheral cell layer - as yet undifferentiated.
This layer is much reduced in the mesial wall.

HUMAN . 40 mm. H. Power.
Calcarine Fissure.



NOTE..

- I. Prominent cortical cell layer - as yet undifferentiated - denser in upper lip of fissure..

HUMAN . 40 m.m.



NOTE.

1. Formation of Choroid Plexus by invagination of the thinned mesial wall.
2. Plexus rudimentary.
3. Its relation to the upper limit of the Foramen of Monro.

General Summary

and

Conclusions,

with a brief Review

of the

Literature.

With the exception of the human foetal series the foregoing account of ^{the} development and histology of the various specimens examined has been written without any previous reference to the literature. In this way an unbiassed description has been given which now comes up for comparison with the results obtained by the many investigators in this field.

Turning to the literature on the subject one found it so enormous that only a certain number of the more important papers could be consulted. Of these, the splendid researches of Campbell and Bolton in this country, and His and Brodmann in Germany, have been most useful.

My results will now be summarized and discussed under the following heads :-

- I. Visual Area.
- II. Rhinic Area.
- III. Cortical cell lamination.
- IV. Development of Brain wall and Cortex.
- V. Choroid Plexus.

I. Visual Area

In the short summary given at the end of each section some reference has already been made to the localization of the Visual Area.

In the Ungulate and Carnivore brains examined it has been pointed out that the cortex of the Gyrus Marginalis possesses a specially distinctive structure, which differs from that on either side of it. These brains possess a well marked Calcarine-Intercalary fissure, the homologies of which have already been discussed,

but /

but the Visual cortex is not limited to the neighbourhood of the fissure but extends round the supero-mesial border and well down on the lateral surface as far as the lateral sulcus. The area is therefore of considerable extent for the marginal gyrus is both long and broad.

In the Rodents the Calcarine Intercalary fissure is absent. The cortex of the mesial surface shows an indeterminate structure somewhat resembling that of the gyrus fornicatus which lies below the Calcarine Intercalary fissure in the Ungulate brains. One therefore looks elsewhere for cortex of a distinctive type and finds it in the wide area extending from the supero-mesial border down on the lateral aspect of the hemisphere to a point not far from the Rhinic fissure and this is considered to indicate the Visual cortex. Again, the area is of considerable extent.

In the Insectivore examined the cortical structure has been shown to be very primitive, and it would be difficult to locate any area probably subserving the Visual function. In view of the mode of life and almost complete blindness of the mole the area would presumably be small, and probably ill-differentiated.

(1) Campbell at the end of his splendid monograph on the 'Histological Localization of Cerebral Function' gives a very valuable appendix of the results obtained by an examination of the cortex of one ungulate and two Carnivore brains. In these he localizes the Visual area with great exactness to the marginal gyrus, and states that it is bounded very definitely by the

Calcarine-Intercalary and lateral sulci. His description of the cell lamination corresponds fairly closely with mine, and he gives in addition an account of the fibre arrangement. In the pig he finds a very characteristic interrupted horizontal band of fibres first described by Xaes, and cortex possessing this band is exactly limited to the marginal gyrus. While in the adult brain one agrees with this precise localization, in the developing brain in the pig and sheep, the limitations of the visual area are not so clearly defined for it has been shown in 13 and 16 cm foeti that the cortex in the lower lip of the Calcarine Intercalary fissure and in the upper part of gyrus fornicatus, is particularly well defined.

(2) Brodmann, as the result of his exhaustive researches on the "Area Striata" or "Calcarina typus" in the various groups of mammals, describes a gradual migration of the Visual area from the lateral to the mesial surface of the caudal portion of the hemisphere as we ascend the Mammalian scale.

In the Insectivora he is uncertain as to the exact position of the area striata in the almost blind mole, but in the better sighted hedge-hog locates a small area of striate cortex on the lateral surface.

In the mole brain previously described it was impossible to pick out any area to which to ascribe the Visual function.

In the Rodents he finds this area easily definable, of considerable extent and placed in the middle part of the lateral surface posteriorly. The area that I have

described /

described as displaying special lamination extends from the supero-mesial border to a short distance above the Rhinic fissure.

In the Ungulates he places the area striata in the marginal gyrus but states that it extends below the limit of the lateral Sulcus, though Campbell in the pig localizes the area exactly to the Marginal gyrus.

(3) Koppen and Lowenstein regard the splenial gyrus as the homologue of the area striata.

In the Carnivora Brodmann agrees with Campbell in the localization of the striate area and places it in the posterior two-thirds of the Marginal gyrus. These conclusions in the Ungulates and Carnivores are in full agreement with the results obtained in the specimens previously described.

Brodmann further goes on to describe the transference of the striate area from the lateral to the mesial surface, till in Man the receptive Visual cortex lies entirely around the Calcarine fissure on the mesial surface though occasionally in the lower types it may extend on to the lateral surface as was found by Elliot Smith in Soudanese, and by Mott in Chinese and Goanese brains.

(4) Munk and Berger experimentally localized the Visual area in the Cat and Dog on the lateral surface posteriorly but this does not correspond with the histological localization of Brodmann and Campbell.

(5) Bolton in a paper on the exact localization of the Visual area in man gives an important review of the subject, based on histology & pathology

(6) Mott gives a very interesting survey of the evolution of the Mammalian Visual cortex and associates the progressive increase in importance and complexity of the Visual area with the full development of Binocular Vision and the appearance of a Macula. He reviews the changes from the Insectivora with their primitive type of cortex up to Man, who possesses two separate Visual areas, which probably subserve different functions.

He strongly supports Bolton's hypothesis of the formation of the cortex on a "granular" basis, and attaches greatest importance to the supra-granular layers of pyramidal cells. The granular layer of Bolton and

Mott is that small celled layer described as (4) or (5) in my text, and they regard this as the fundamental layer of the cortex, to which additions are made above and below, but especially above in the higher orders.

The overlying pyramidal cells are called supra-granular. In the Mole the supra-granular cortex is extremely rudimentary and pyramidal cells are practically absent. The paucity and poor development of the surface cells have been noted in my specimen.

In Rodents the supra granular pyramids are well developed and Mott co-relates this with the extensive panoramic vision of this group.

In Ungulates the visual area is relatively of large size and the surface pyramids fairly well developed. This group has panoramic plus some binocular vision.

In Carnivores the supra granular layer is particularly well developed and in both Cat and Dog numerous large vertical pyramids are present just above the granular layer. Mott co-relates this with Binocular-Stereoscopic

vision.

In Man the supra granular layer has advanced greatly, and the small, medium and large pyramids are regarded by most observers as the important Visuo-Sensory cells. With the histological facts upon which the above inferences are based by results are in complete accordance.

- (7) Watson, also working on the "granular basis" hypothesis has given a survey of the cortex of the Insectivora. He at first localized the Visual cortex of the Mole in an indifferentiated area on the caudal infero-mesial aspect of the hemisphere, but in a later paper admits that this is probably incorrect.
- (8) Abel in a topographical survey of the cortex of the guinea-pig comes to the conclusion that the sensory area is diffuse.
- (9) Bevan Lewis as far back as 1878 wrote an excellent account of the histology of the cortex of the sheep and pig, but gave no special consideration to the Visual area.

II. Rhinc Area.

Throughout the series of brains examined this has been shown to possess a very characteristic cortical structure which is of a much more primitive type than the overlying Neopallium. This might be expected from its older position in the process of evolution. In all cases it is very clearly demarcated from the Neopallial cortex even in the absence of the Rhinc fissure.

This differentiation is clearly marked at a very early

stage in the process of development as has been shown in the series of Ungulate, Carnivore and Rodent brains. The area is capable of subdivision into three parts :-

1. Upper junctional adjoining the Rhinic fissure above.
2. Middle occupying the infero-mesial border of the hemisphere and possessing a characteristic structure.
3. Lower junctional which turns upwards on the mesial surface and joins the Cornu Ammonis. The latter is characterized by the layer of very large cells and the superjacent radial striation.

The central portion of the area calls for special comment :-

1. The Molecular layer is very deep and clear.
2. The cells generally are large and differ from those of the Neopallium in being arranged quite irregularly and having lost the pyramidal shape. The lamination is also much reduced.
3. The superficial polymorph cells show a marked tendency to form clusters. This is extremely characteristic of the area in all brains examined.

(10) Professor Schäfer notes the nested arrangement of the superficial polymorphs in the Human Hippocampal gyrus. Campbell and Brodmann have also drawn attention to the above points.

III. Cortical Cell Lamination.

One may say at the outset that the Literature on this subject is complicated by the fact that each observer adopts terms of his own for the various layers, and again differ in the number of layers to be defined in the same area of cortex. Brodmann attempts to

reduce the cortex generally to a six-layered type, and this I strongly support. Deviations of course occur but Brodmann considers that the six-layered type can always be recognised at some period of development. The most interesting variation occurs in the Human

(11) Visual cortex, which Cajal separates into nine layers. Thus increase results from a splitting of one of the primary layers by the fibre layer of Gennari.

(12) Bolton adopts a very simple nomenclature, based according to his own observations upon both function and development. He states that the cortex is laid down on a "granular basis" to which additions are made above and below.

The superficial pyramidal cells he calls the supra-granular layer, and the deep polymorph the infra-granular, and to these layers he ascribes different functions.

The Supra granular pyramids are probably concerned with the higher functions associated with increased intelligence, according to Bolton's developmental and pathological researches, and this view is supported by Mott and Cajal.

My observations would support this view for the Carnivore brains show a much greater development of the surface pyramids than any of the lower types, for the layer is relatively deep, and the cells can readily be subdivided into small, medium and large pyramids. In the Rodents the layer is considerably reduced and in the Mole the surface cells are very scanty and their type is altered.

In general then, one concludes that the brains examined

conform /

conform to a definite six layered type of cell lamination. To this the Mole is an exception.

My results also agree fairly closely with those of Brodmann as regards variations in the different layers. He concludes that, ascending the Mammalian series, the greatest amount of differentiation occurs in the pyramidal layers, which increase in depth; that the sixth or deepest layer shows the greatest variation in depth - a point which has been noted in my specimens in different areas; that in Rodents the layer of large deep pyramids is relatively increased - which point has already been illustrated in the Rabbit.

(13) Jacobi gives a general survey of cerebral structure through the different orders, on the same lines as Brodmann and with general similar results.

IV. Development of Brain Wall and Cortex.

This has been studied in its various stages in full series of Sheep, Pigs and Ferrets, and in Man during the early months. The early stages of all exactly resemble one another.

The first stage displays the most primitive structure of the brain wall, which consists simply of an aggregation of actively growing and dividing round neuroblasts, enclosed by limiting membranes.

The second stage shows the brain wall to consist of three layers conveniently called :-

1. Peripheral Reticular.
2. Mantle or cellular layer.
3. Ependymal or Epithelial layer.

Of these the Mantle is the most important, and around it centre all the important subsequent changes.

The third stage shows that the outer cells of the Mantle layer become split off from the main layer and migrate outwards to the periphery where at first they form an extremely narrow band. This layer of cells represents the early rudiment of the cellular cortex and from now on the foetus embarks upon a second period of development in which the cortical band becomes greatly increased in depth and complexity till it forms the many layered adult cortex.

Co-incident with this the remainder of the original mantle layer surrounding the ventricle undergoes a steady reduction, being ultimately reduced to an extremely fine layer around the ependyma though at the lower pole of the ventricle anteriorly it is increased to form the cellular basis of the Basal ganglia.

This splitting of the mantle layer takes place at a very early stage in development for the cortical layer is well defined in 4c.m. sheep and pigs and in an 8 mm. ferret. The subsequent changes in the cortex consist in a rapid increase in depth and complexity, and the differentiation of the various layers. Having once begun this goes on very rapidly. These changes have already been detailed so fully in previous sections that no more need be said.

One may conclude that :-

1. In the Ungulates the period of most rapid cortical development occurs between 10 and 20 cms.
2. Cortical differentiation proceeds pari passu with cortical fissuration for by the time the foetus has

reached /

reached a length of about 20 cms. the main fissures are all well developed and the cortex has attained the adult type of cell lamination.

14. Fragnito has described the early development of the Mammalian cortex and his results are very similar in general to mine. He notes the migration outwards of the mantle cells to form the early cortical layer, and discusses whether the pointed end of the Neuroblasts represents the axon.

16. His has described the development of the brain wall in the early months in the Human foetus^{So}/completely that nothing more need be said, as my results tally very closely with his.

V. The Choroid Plexus.

This has been shown to arise from an invagination of the greatly thinned mesial brain wall in the region of the upper end of that canal which represents the Foramen of Monro in the early stages of development. This invagination is produced by one of the pial blood vessels and at first is a short finger-like process consisting of a central vessel covered by tall columnar epithelial cells. Subsequently this process becomes greatly convoluted and at the same time the Choroidal Epithelium undergoes reduction till the cells finally become Cuboidal. The resemblance of the Choroidal Epithelium to secreting cells has already been commented on, and a full description of the development of the plexus has been given in the case of the Sheep and Ferret, illustrated by micro photographs.

In the adult, the stalk of the plexus of the lateral ventricle retains its original relation to the foramen of Monro.

In conclusion, I must offer my best thanks to Professor Robinson for his help, and for many stimulating suggestions.

I must also thank Mr. Ernest Henderson of the Anatomy Department for the care and skill he has bestowed upon the Micro-photography.

Lastly, I must acknowledge my indebtedness to the Moray Research fund, for the defrayal of part of the cost of this research.

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The Changes
in the
Optic Nerve, Chiasma and Tracts
of a Man
whose Right Eye
had been enucleated
one year before death.

"Appendix of Results obtained from the Examination of the Optic Nerves, Chiasma and Tracts of a Human Subject from whom the Right Eye had been Enucleated one year before death."

Method of Examination.

The Brain was hardened for a long period in Muller-Formol mixture and then the occipital lobes and Optic Apparatus were after hardened in increasing strengths of alcohol. Finally the Optic Nerves, Chiasma and the free portions of the Tracts were divided into separate blocks, embedded in Paraffin and cut in serial section at a thickness of 10 micros.

1. The Optic Nerves were removed as they emerged from the Chiasma, and were sectioned transversely.
2. The Optic Tracts were cut as they emerged from the Chiasma in front and at the Crus Cerebri behind, and were also cut transversely.
3. The Chiasma, was cut in serial section from side to side in the antero posterior plane. The sections were then stained by the Weigert Pal method and counter-stained by Van Gieson's stain. Some difficulty was experienced at first in getting the sections to take up the Acid Haematoxylin and it was found that the best results were obtained by incubating them at 37°C, both while in the Marchis fluid and in the logwood.

This method has given good general effects in following out the course of the path of degeneration and in addition some sections have been specially prepared to demonstrate the overgrowth of Neuroglia in the degenerated areas. The method used was a modification of the

Anilin /

Anilin Blue method and gave good results.

1. Stain sections with 1% Anilin Blue 15-20 mins.
2. Wash well with D-water to remove the excess of stain, but be careful not to take out too much of the colour as this is readily done. The sections should be of a deep blue colour finally.
3. Dry completely as in making a film preparation.

The Right Optic Nerve. The sections show an entire absence of myelinated nerve fibres and bleached with great rapidity. The Neuroglia has proliferated and this Sclerosis is most marked centrally. The Weigert preparations show a lack of detail, and the Anilin-Blue method gives a clearer picture of the Neuroglia. The Central Sclerosis is again very clearly marked, both under low and high forms. The Neuroglia cells are of varying size, both types appear to be present and they possess a wealth of fibres. These radiate from the cells and form a close interlacement throughout the section, especially centrally, while peripherally the network is opener. There is no evidence of any normally staining fibres.

The Left Optic Nerve. The sections have taken up and retained the acid logwood quite normally. The Nerve fibres are deeply stained and towards the centre appear to be uniformly smaller and more closely packed than at the periphery.

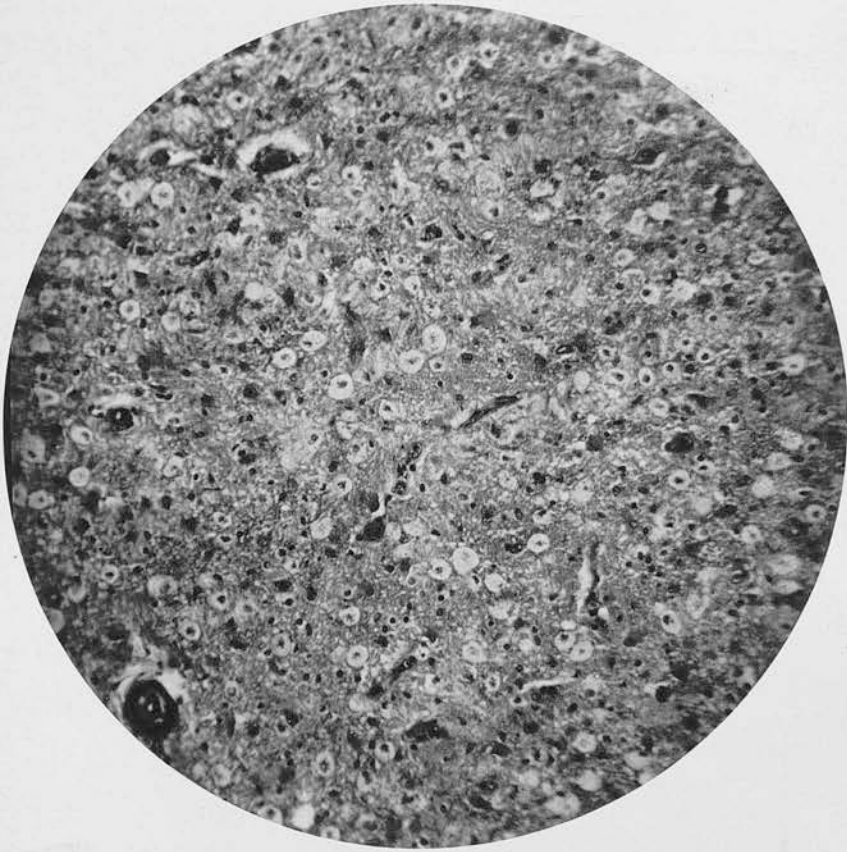
There is no trace of any degenerated fibres passing outwards in the nerve.

Anilin Blue preparations display the neuroglia which is small in amount and scattered throughout the section. The cells are mostly small, while towards the periphery

there /

Right Optic Nerve.

Weigert Pal.

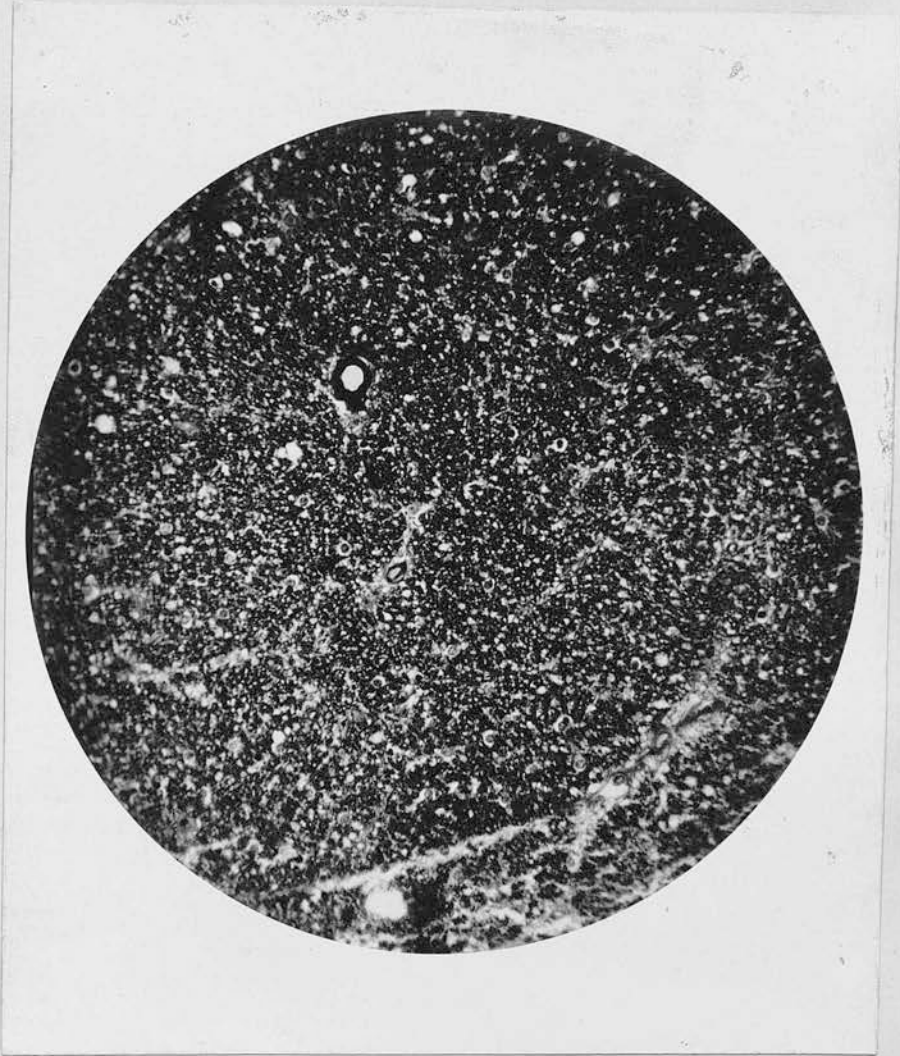


NOTE.

Complete degeneration.

Left Optic Nerve.

Weigert Pal.



NOTE.

Normal staining of section.

there are larger cells with more evident processes.

The Optic Chiasma. The degenerated fibres will be traced backwards through the Chiasma from their entrance by the Right Optic Nerve, and the sections will be considered from right to left.

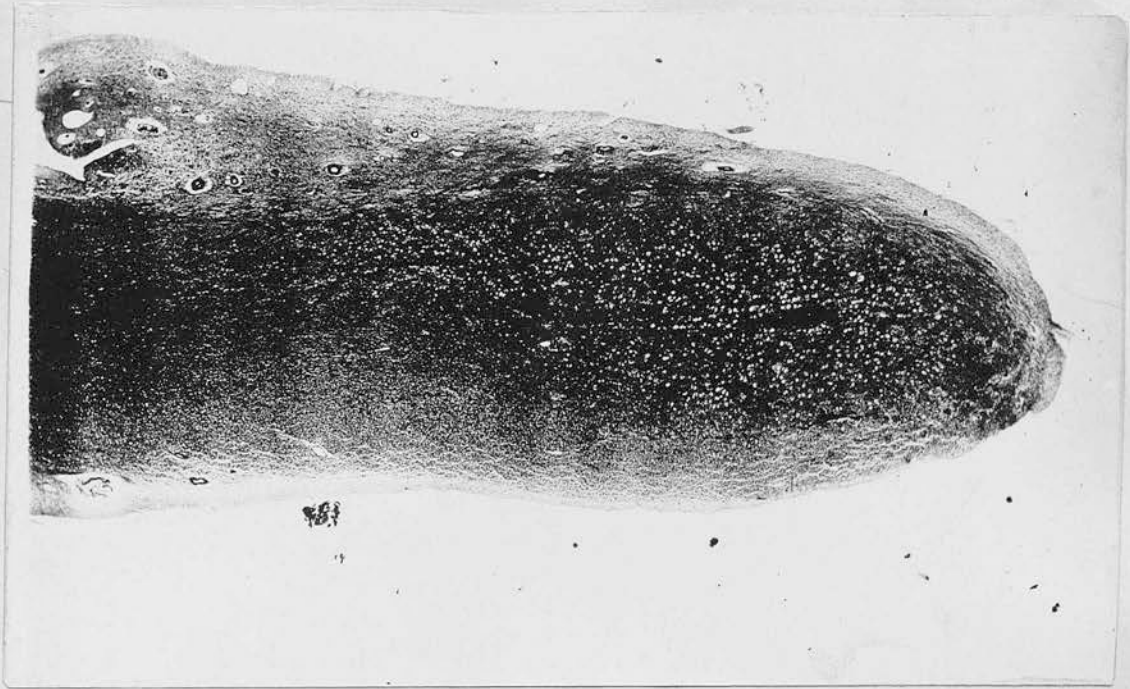
The earliest sections show the degenerated Right nerve entering the Chiasma and the most external fibres pass back to enter the Right Optic tract where they mingle with normally staining fibres while the inner fibres pass obliquely back and to the left to enter the Chiasma. Later sections show this better and the degenerated fibres entering the Right tract are seen to take up their position mostly to the centre and inner side, whilst externally there are normal fibres. The sclerosed tissue is well defined, being deeply stained by the fuchsin and it appears as wavy bundles of fibres. In later sections the central position assumed by the degenerated fibres in the Right tract is still better defined and this will be referred to later under the description of the Right Tract.

Later sections show that the decussating degenerated fibres from the Right Optic Nerve are placed dorsally where they form a triangular area of degeneration with the apex behind. As the sections approach the centre of the Chiasma the degenerated area occupies the anterior part of the Chiasma and extends backwards as a triangular strip dorsally.

Later the degenerated area seems to extend still further to the dorsal aspect, and a band of normal fibres passes forward into the anterior part of the Chiasma and lies behind its anterior free border.

Optic Chiasma,

Weigert Pal.



NOTE.

1. Section from right side of Chiasma.
2. Crossing degenerated^d fibres from Right Optic Nerve lying dorsally, and extending forwards into the free border.

Still later sections show that the degeneration gradually becomes more centrally placed and is surrounded by normal fibres. These appear as a narrow strip dorsally and this gradually widens and pushes the degenerated fibres nearer the centre.

At this point two additional points of interest may be noted :-

1. In the grey matter of the Locus Performatus Anticus a very distinct group of deeply staining medullated Nerve fibres appears lying quite behind the Chiasma.

2. Near the centre of the Chiasma a large blood vessel appears, and this takes a peculiar curved course through the Chiasma towards its anterior part. It arises from a fairly large trunk on the dorsal aspect, runs parallel to and near the upper surface and then near the junction of the anterior fourth and posterior three fourths of the Chiasma curves downwards and forwards to reach the under surface where it ends in small branches. The size and course of this vessel make

one suggest that it may be of some clinical and pathological importance, for Thrombosis or Embolism might occur in it and lead to one or other type of Hemianopia. Similarly the pressure exerted by an enlarged Pituitary might affect it injuriously and lead to changes in the Chiasma either mechanically or by acting on the blood flow. It may be an inconstant vessel but its presence in this case is worth noting.

The decussating degenerated fibres in their course to the left tract have been shown to become centrally placed as the centre of the Chiasma is reached and after passing the centre the degeneration is seen to

leave /

Optic Chiasma,

Weigert Pal.

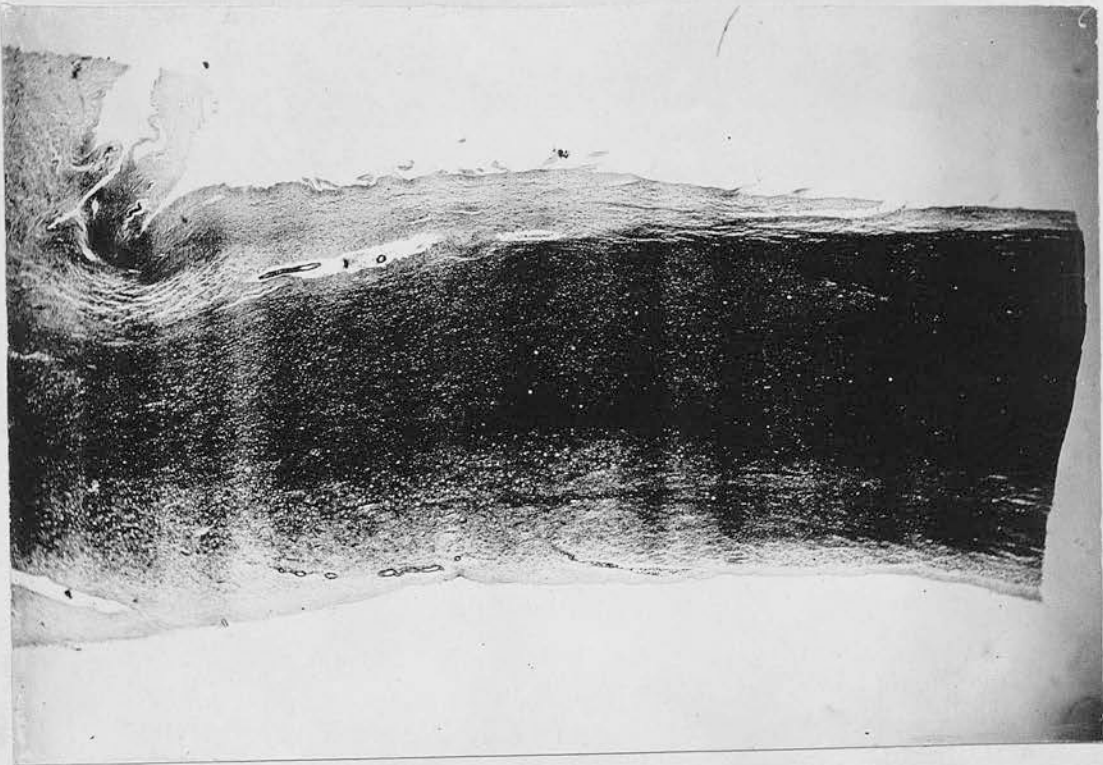


NOTE.

1. Section from centre part of Chiasma.
2. Crossing degenerated fibres from Right Optic *d*
Nerve lying centrally in the concavity of
the vessel.
3. The large vessel described in the text.

Optic Chiasma,

Weigert Pal.



NOTE.

1. Section from left border of Chiasma.
2. Normal dark fibres of Left Optic Nerve.
3. Crossed degenerated fibres from Right Optic Nerve.
lying ventrally.

leave the centre and to pass more ventrally, till finally it forms a triangular area extending from the anterior edge of the Chiasma back to the base. Hence a very distinct change occurs as the degenerated fibres from the Right Optic Nerve pass across to join the Left Optic Tract, for in this case they lie first dorsally, gradually become central and finally lie entirely ventrally in the Chiasma.

As the sections approach the entrance of the Left Optic Nerve the ventral degeneration is better seen and is covered dorsally by deeply staining fibres running transversely and obliquely. The normal Left Optic Nerve then appears sending its fibres back into the Chiasma. Anteriorly the degenerated and normal fibres are clearly demarcated but posteriorly they mingle to some extent. Later sections show a narrow strip of degeneration passing forwards towards the entering Left Optic Nerve wedged in between normal fibres, and at the left edge of the Chiasma the degenerated and normal fibres mingle still more closely as the direct fibres from the Left Nerve meet those which have crossed from the Right. As the sections pass into the issuing Left Optic Tract the line between normal and degenerated fibres is indistinct but ventrally there is a distinct band of total degeneration and the fibres which stain most deeply are central.

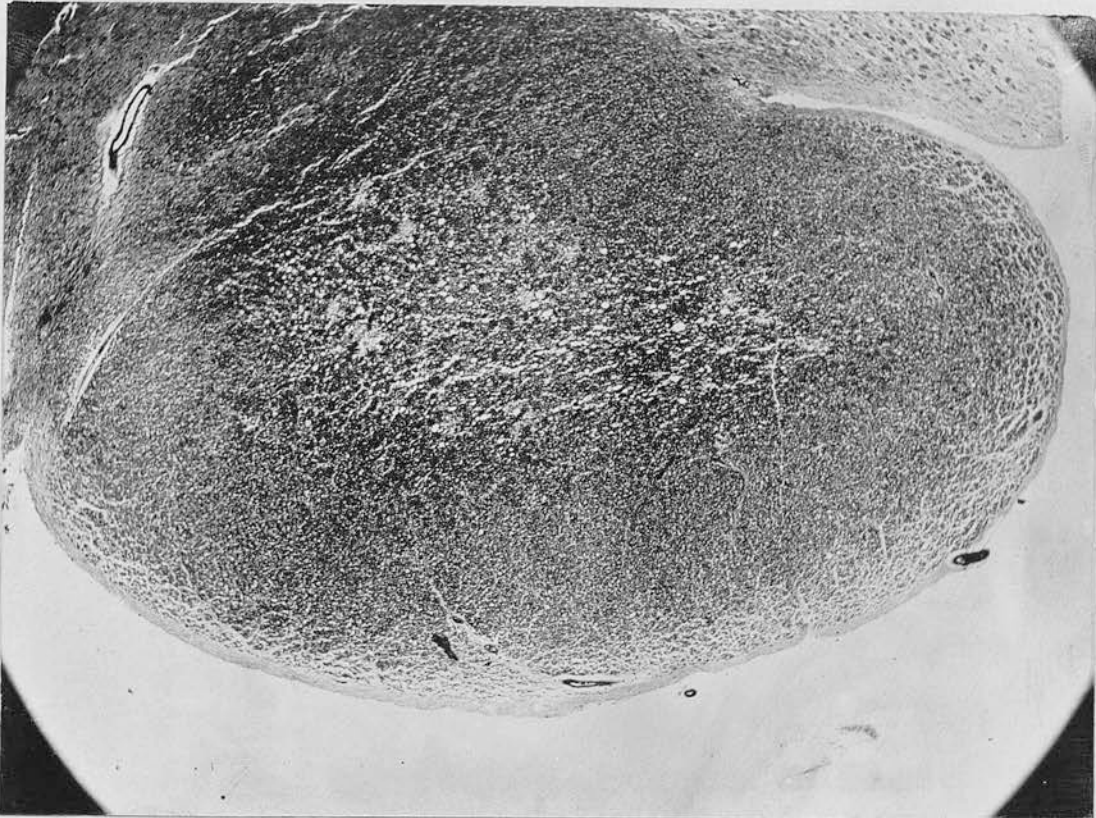
The final sections give a similar result and the degenerated fibres have become peripheral and are placed chiefly on the ventral surface of the Left Optic Tract.

Right Optic Tract. In the transverse sections the degenerated fibres from the Right Optic Nerve are placed

centrally /

Right Optic Tract.

Weigert Pal.



NOTE.

Central degeneration extending into attached
border.

centrally and extend into the attached border of the tract. Around the Periphery the fibres appear quite normal and stain deeply, and are divided into two layers:-

1. Peripheral, where the fibres are larger in size and fewer in number.
2. Deeper, which lies between the periphery and the degenerated central fibres. Here the fibres are closely packed and are of uniform small size. Weigert preparations show a lack of detail but the Anilin-Blue method brings out the details of the Sclerosis. The central area of the tract is occupied by proliferated Neuroglia tissue, consisting of cells of varying size and the network formed by their fibres. The Sclerosed area is clearly marked off from the normal which shows only a few Neuroglia cells here and there, and the Sclerosis extends towards the attached border of the tract. The peripheral neuroglia is also well stained and is remarkable for the large size of the cells. Lying at the base of the tract there is a separate and very distinct group of deeply staining medullated fibres lying quite apart from the actual tract.

Left Optic Tract. This shows entirely different appearances from the Right. Weigert preparations show the crossed degenerated fibres from the Right Optic Nerve placed peripherally. They occupy the free border of the tract and extend thence round the lower border right to the base.

Anilin-Blue preparations show greater detail and define the limits of the sclerosed area quite definitely. The Neuroglia has markedly proliferated and the

peripheral /

Left Optic Tract.

Weigert pal.



NOT E.

Peripheral degeneration especially at the free
border and along the lower surface.

peripheral situation of the degenerated fibres is very distinct.

Lying close to the attached border of the tract there is a group of deeply stained fibres similar to that on the Right side.

Conclusions. One must conclude from a study of this particular case that :-

1. The Direct fibres of the Right Optic Nerve (degenerated) pass back and assume a more or less central position in the Right Optic tract.
2. The Crossed fibres from the Right Optic Nerve, after reaching the Left side assume a peripheral position, lying mostly on the lower aspect of the Left Optic tract. This of course only holds for the portions of the optic tracts examined, and whether the degenerated fibres change their position remains to be seen in the examination of those parts of the tracts connected with the mid-brain.
3. These Crossed fibres at first lie dorsally in the Chiasma, become central near the centre of the Chiasma and finally become ventral before entering the Left tract.
4. The ^{pro-}portion of crossed and direct fibres from the Right Optic Nerve is roughly the same.
5. There is no evidence of any undegenerated fibres in the Right Optic Nerve. At first sight there appeared to be a few medullated fibres placed peripherally but

on closer examination these were seen to be elastic fibres belonging to minute blood-vessels. There is, therefore, no evidence of Centrifugal fibres passing out in the Right Optic Nerve to the Retina.

The failure to find the above sets of fibres in this case perhaps depends upon a lack of refinement in the staining methods.

Most observers agree that these efferent fibres are of much finer calibre than the afferent.

6. The separate band of dark stained medullated fibres which appear at the base of each optic tract and cross in the Chiasma is apparently a separate commissural band and has no connection with the Optic Nerves.

It is Gudden's commissure and connects the mesial Corpora Geniculata but probably has no relation to the Visual function.

The Literature on this subject may now be referred to briefly. In some lower mammals such as the mouse the decussation of the Optic fibres in the Chiasma is complete but in the higher mammals and in Man it is only partial as is definitely proved for the case just described. The relative position of the crossed and direct fibres in the Chiasma and tracts is variously stated by different observers. In the present case the degenerated fibres from the Right Optic Nerve take up very definite positions in the Chiasma and tracts and my conclusions are supported by many other cases. Warrington and Dutton (1) describe a case of Right Optic Atrophy very similar to mine, with very similar results. They note the presence in the degenerated nerve of scattered small undegenerated fibres, and state that similar small fibres occur in the degenerated portions of the Tracts. These are considered to be centrifugal.

Williamson (2) gives a very clear account of a similar case.

Purtscher (3) describes six similar cases.

Hellandal (4) and Siemerling (5) also have described like cases.

It has been noted in the present case that there is no trace of degenerated fibres in the Left Optic Nerve and therefore no evidence of the presence of Inter-Retinal fibres ~~and~~ the Vordere Bogen Commissur of Stilling.

There is however some pathological and experimental evidence of the existence of such fibres.

Parsons (6) in the course of an experimental investigation in monkeys found that after producing lesions in one eye, degeneration existed in both Optic nerves. Dean and Usher (7) and Pick (8) obtained similar results.

It has been suggested that these inter retinal fibres perhaps arise from a division of the Optic nerve fibres for Cajal has proved that they bifurcate. The degenerated fibres in the opposite nerve may therefore represent branches from the injured side.

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